CROOKED LAKE
LAKE CLASSIFICATION REPORT

Presented by Reesa Evans, CLM, Lake Specialist
P.O. Box 287, Friendship, WI 53934

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Table of Contents
Crooked Lake Classification Report

EXECUTIVE SUMMARY

Background Information about Crooked Lake

Crooked Lake, a natural seepage lake, is located in the Town of Jackson, Adams County in the Central Sands area of Wisconsin. It has 48 surface acres, with a maximum depth of 56 feet and a mean depth of 14 feet. The Wisconsin Department of Natural Resources has designated Crooked Lake as an outstanding waterbody with a forested wetland corridor on the western/southwestern part of the lake that extends over 500' inland from the ordinary high water mark of the lake. Currently, Crooked Lake is the only lake so designated in Adams County.

This lake has no natural stream inlet or outlet and fed by precipitation, runoff and groundwater. Crooked Lake is part of the Neenah Creek Watershed, a large watershed of 182 square miles which flows into the Fox River and eventually into Lake Michigan. There is a public boat ramp on the north side of the lake, owned by the Adams County Park Department. There are three Native American archeological sites, mostly burial mounds, located around Crooked Lake that cannot be further disturbed without permission of the federal government and input from the local tribes.

Except for some pockets of muck and silt loam, the soils in the surface watershed are mostly loamy fine sand and fine sandy loam second. In the ground watershed for Crooked Lake, sand dominates, with loamy sand second. These soils tend to be well or excessively drained, no matter what the slope. Water, air and nutrients move through these soils at a rapid rate, so that little runoff occurs unless the soil becomes saturated. Wind erosion, water erosion and drought are common hazards of these soil types.

Land Use in Crooked Lake Watersheds

Both the surface and ground watersheds of Crooked Lake are fairly small. Overall, the three most common current land uses in the Crooked Lake surface watershed are non-irrigated agriculture, woodlands and residential, in that order. More than 1/2 of Crooked Lake's shore has wetlands at or near the shore that serve as filters and traprs that help keep the lake as clean as it is. Wetlands also play several important roles in maintaining water quality, in the aquatic food chain and in wildlife nesting. It is essential to preserve these wetlands for the health of Crooked Lake.

The land use in the ground watershed is somewhat different. The most common land use in the ground watershed is woodlands, followed by non-irrigated agriculture, which is closely followed by residential land.

Crooked Lake has a total shoreline of 2.22 miles (11,721.6 feet). The shore consists of privately-owned lots and a boat ramp area owned by the Adams County. Many of the shores, especially on the south side of the lake, are steeply sloped. Buildings are generally located 70 or more feet back from the shore. Many of the privately-owned lots have not been developed.

A 2004 shoreline survey showed that 100% of Crooked Lake’s shore is vegetated, although not all with native vegetation. The 2004 inventory also classified shorelines has having “adequate” or “inadequate” buffers. An “adequate” buffer was defined as one having the first 35 feet landward covered by native vegetation. An “inadequate” buffer was anything that didn’t meet the definition of “adequate buffer”, including native vegetation strips less than 35 feet landward. 16.28% of Crooked Lake’s shoreline had an “inadequate buffer.”

Most of the “inadequate” buffer areas were found with mowed lawns and/or insufficient native vegetation at the shoreline to cover 35 feet landward from the water line. Adequate buffers on Crooked Lake could be easily installed in the inadequate areas by either letting the first 35 feet landward from the water just grow without mowing it, or—if something more controlled or aesthetically pleasing was desired—by planting native seedlings sufficient to fill in the first 35 feet.

Water Testing Results

Between 2004 and 2006, Adams County Land & Water Conservation Department gathered water chemistry and other water quality information on 20 lakes in Adams County with public access. Crooked Lake was one of these lakes. Overall, Crooked Lake was determined to be a mesotrophic lake with very good water quality and water clarity.

Measuring the phosphorus in a lake system provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. The 2004-2006 summer average phosphorus concentration in Crooked Lake was 18.8 micrograms/liter. This is below the 25 micrograms/l average recommended for natural lakes in Wisconsin to avoid algal blooms. This concentration suggests that Crooked Lake is likely to have few nuisance algal blooms. This places Crooked Lake in the “good” water quality section.

Water clarity is a critical factor for plants. If plants don't get more than 2% of the surface illumination, they won't survive. Water clarity is measured with a Secchi disk. Average summer Secchi disk clarity in Crooked Lake in 2004-2006 was 10.6 feet. This is very good water clarity. Records since 1990 show that the water clarity in Crooked Lake has consistently remained high.

Chlorophyll-a concentrations provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth, as well as result in unpleasing odor and appearance. The 2004-2006 summer (June-September) average chlorophyll-a concentration in Crooked Lake was 4.4 milligrams/liter, a low algal concentration. Chlorophyll-a averages have stayed low in Crooked Lake since 1992, the first year for which records were found.

Low dissolved oxygen levels during the summer in the bottom waters of a lake occurs naturally as oxygen in the bottom layer is consumed, but not replenished. As the summer progresses, the oxygen concentration of the bottom waters may decrease. In Crooked Lake, there were hypoxic (low oxygen) periods in the depths from 25' to 50' during the summers of 2004 and 2005. Besides being a potential danger to a lake's fish population, summer hypoxia can result in phosphorus being released into the upper water column and being available for algal blooms and increased aquatic plant growth. The data collected at Crooked Lake from 2004-2006 shows there is a potential for phosphorus loading from the lower depths (hypolimnion) during the summer months in Crooked Lake if the hypoxia/anoxia continues. Dissolved oxygen needs to be monitored during the late summer months in the lower depths on Crooked Lake to determine whether hypoxia/anoxia is a frequently-occurring condition that may need to be addressed by management practices.

Water testing results for Crooked Lake showed "very hard" water (204 mg/l $CaCO_3$). Hard water lakes tend to produce more fish and aquatic plants than soft water lakes because they are often located in watersheds with soils that load phosphorus into the lake water. Hardness levels over 180 mg/l can cause marl to start precipitating out of the water or sediment, thus releasing phosphorus for aquatic plant and algae use. Since Crooked Lake's hardness less is far below that, the marl in the lake is likely to keep binding a significant amount of phosphorus that would otherwise be in the water column.

A lake with a neutral or slightly alkaline pH like Crooked Lake is a good lake for fish and plant survival. Natural rainfall in Wisconsin averages a pH of 5.6. This means that if the rain falls on a lake without sufficient alkalinity to buffer that acid water coming in by rainfall, the lake's fish cannot reproduce. That is not a problem at Crooked Lake.

Other water quality testing at Crooked Lake showed no particular areas of concern. The average calcium level in Crooked Lake's water during the testing period was 43.12 mg/l. The average Magnesium level was 21.97 mg/l. Both of these are low-level readings. The presence of a significant amount of chloride over a period of time may indicate that there are negative human impacts on the water quality present. Chloride levels found in Crooked Lake during the testing period were all significantly above 3 mg/l, at about the natural level of chloride in this area of Wisconsin. This needs to be investigated. Nitrogen levels can also affect other aspects of water quality. The sum of water testing results for nitrate, nitrite and ammonium levels of over .3 mg/l in the spring can be used to project the likelihood of an algal bloom in the summer (assuming sufficient phosphorus is also present). Crooked Lake nitrogen-combination spring levels from 2004 to 2006 never rose to more than .19 mg/l, significantly below the .3 mg/l predictive level.

Both sodium and potassium levels in Crooked Lake were very low: the average sodium level was 1.75 mg/l; the average potassium reading was .7 mg/l. To prevent the formation of H2S, levels of 10 mg/l are best. A health advisory kicks in at 30 mg/l. Crooked Lake sulfate levels average 8.82 mg/l during the testing period, far below either level. Turbidity reflects water clarity. The term refers to suspended solids in the water column—solids that may include clay, silt, sand, plankton, waste, sewage and other pollutants. Very turbid waters may not only smell and mask bacteria & other pollutants, but also tend to be aesthetically displeasing, thus curtailing recreational uses of the water. Turbidity levels for Crooked Lake's waters were all at very low levels.

Phosphorus

Like most lakes in Wisconsin, Crooked Lake is a phosphorus-limited lake: of the pollutants that end up in the lake, the one that most affects the overall quality of the lake water is phosphorus. The amount of phosphorus especially affects the frequency and density of aquatic vegetation and the frequency and density of various kinds of algae, as well as water clarity and other quality aspects.

The total phosphorus (TP) concentration in a lake is considered a good indicator of a lake's nutrient status, since the TP concentration tends to be more stable than other types of phosphorus concentration. For a natural lake like Crooked Lake, a total phosphorus concentration below 20 micrograms/liter tends to indicate few nuisance algal blooms are likely to occur. Crooked Lake's growing season (June-September) surface average total phosphorus level of 18.8 micrograms/liter is low enough so that nuisance algal blooms should occur rarely and are probably localized.

In most lakes in Wisconsin, phosphorus concentration in the bottom sediments of the lake is considerably higher than the concentration in the water column itself. Bottom sediments can “bind up” phosphorus, making it unavailable for aquatic plants or algae to use. Some sediment types hold phosphorus at a higher rate than others. Crooked Lake is lucky to have a substantial amount of marl in its sediments. “Marl” is a calcium carbonate precipitate (solid) that forms in hardwater lakes when both calcium and pH levels are high and has a high capacity to immobilize phosphorus and other nutrients. With such a large amount of marl sediment, Crooked Lake may benefit from it removing phosphorus from water column, thus making it unavailable for algal and aquatic plant growth.

Land use plays a major role in phosphorus loading. The land uses in the Crooked Lake surface watershed that contribute the most phosphorus are non-irrigated agriculture and woodlands, with residential use a third significant contributor. Some phosphorus deposition cannot be controlled by humans. However, some phosphorus (and other nutrient) input can be decreased or increased by changes in human land use patterns. Practices such as waterbody shoreland buffer restoration; infiltrating stormwater runoff from roof tops, driveways and other impervious surfaces; using no phosphorus lawn fertilizers; and reducing phosphorus input to and properly managing septic systems will minimize phosphorus inputs into the lake.

Reducing the amount of input from the surface and ground watersheds results in less nutrient loading into the lake itself. Under modeling predictions, reducing phosphorus inputs from human-based activities even 10% would improve Crooked Lake in-lake water quality by 2 to 4 micrograms of phosphorus/liter; a 25% reduction would save 4 to 11 micrograms/liter. Currently, both the spring turnover and summer phosphorus levels are below the threshold value of 20 micrograms/liter, but a phosphorus increase from human activities of only 25% would put the phosphorus levels in the lake over that threshold in the summer. The result would be more algal blooms and more aquatic plants. The modeling predictions make it clear that reducing current phosphorus human-impacted inputs to the lake are essential to improve, maintain and protect Crooked Lake’s health for future generations.

Aquatic Plant Community

The aquatic plant community of Crooked Lake is characterized by good quality and very good species diversity. The plant community suggests that Crooked Lake is closer to an undisturbed condition than the average lake in the state. In the North Central Hardwoods Region, Crooked Lake is in the group of lakes closest to an undisturbed condition.

The Crooked Lake aquatic plant community has colonized 67% of the littoral zone and about half the lake. The 0-1.5' depth supported the most abundant aquatic plant growth. The dominant species in Crooked Lake was *Chara* spp (muskgrass, a plant-like algae). Sub-dominant was *Nymphaea odorata* (white water lily). A plant of special concern, *Eleocharis quadrangulata* (square-stem spikerush), was also found at Crooked Lake.

Myriphyllum spicatum (Eurasian watermilfoil), an aggressive invasive species, was found in Crooked Lake during the 2005 aquatic plant survey. A rough field survey in 2007 showed the plant had spread, although still only in water less than 5' deep and still fanning either direction near the boat ramp. The Crooked Lake Association has been engaging in some hand-pulling since 2005, but more aggressive treatment may need to be taken to prevent further spread. A survey in 2007 indicated that the native weevil, *Euhrychiopsis lecontei*, was present in parts of Crooked Lake. This weevil, if present in sufficient density, can weaken Eurasian milfoil plants to the point of death.

<u>Critical Habitat Areas</u>

Wisconsin Rule 107.05(3)(i)(I) defines a "critical habitat areas" as: "areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water. Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, critical habitat areas often can provide the peace, serenity and beauty that draw many people to lakes. Three areas on Crooked Lake—covering most of the lake's shores--were determined by a team of lake professionals to be appropriate for critical habitat designation.

CR1 extends along approximately 4200 feet of the shoreline. 24% of the shore is wooded; 27% has shrubs; 49% is native herbaceous cover. Several types of wetlands are found along this shoreline: shallow marsh; deep marsh; sedge meadow; shrub-carr; and tamarack bog. Large woody cover is common for habitat. With virtually no human disturbance along this shoreline, the area has natural scenic beauty. One threatened aquatic species, *Eleocharis quadrangulata*, was found along this sensitive area. Aquatic plants included three emergent species, two floating-leaf rooted species, two free-floating species and ten submergent species.

CR2 extends along approximately 2900 feet of the shoreline. 40% of the shore is wooded; 10% has shrubs; 50% is native herbaceous cover. Sedge meadow and tamarack bog wetlands are found along this shoreline. Large woody cover is abundant for habitat. With little human disturbance along this shoreline, the area is has natural scenic beauty. The invasive, *Myriophyllum spicatum* (Eurasian watermilfoil) was found here, as well as three emergent species, two floating-leaf rooted plants, and thirteen submergent aquatic species.

CR3 extends along approximately 3300 feet of the shoreline. 7% of the shore is wooded; 20% has shrubs; 57% is native herbaceous cover—the remaining 21% is cultivated lawn. This sensitive area includes the most developed area of Crooked Lake. However, there are areas of wetlands: shallow marsh; sedge meadow; and conifer swamp. Large woody cover is present, but not as much as in the other two sensitive areas. Scenic beauty in part of the area is lessened due to the human development. Most development in this area has been carried out so as to preserve habitat and minimize negative human impact, although native vegetation buffers need to be increased. Eurasian watermilfoil was also found here. Other aquatic species included four emergent species, two floating-leaf rooted plants, one free-floating aquatic species and ten submergent species.

Fish/Wildlife/Endangered Resources

Stocking records for Crooked Lake go back to 1937, when northern pike and mixed panfish were stocked by the WDNR. Over the years since, the WDNR also stocked more mixed panfish, perch, largemouth bass, bullhead, northern pike, and both rainbow and brooked trout. Fish inventories from 1954 through 1985 found that largemouth bass, bullheads and panfish were common to abundant, while northern pike tended to be scarce. Trout apparently did not establish a breeding population, since an inventory three years after trout were last stocked found no trout present.

Muskrat and mink are also known to use Crooked Lake shores for cover, reproduction and feeding. A beaver lodge was noted during the critical habitat survey. Seen during the field survey were various types of waterfowl, songbirds, and turkey. Frogs and salamanders are known, using the lake shores for shelter/cover, nesting and feeding. Turtles and snakes also use this area for cover or shelter in this area, as well as nested and fed in this area. Sandhill cranes have also nested on Crooked Lake. Upland wildlife feed and nest here as well.

The Crooked Lake watersheds shelter several natural communities designated by the WDNR as communities that are endangered: Calcareous fen; Emergent marsh; Northern sedge meadow; Oak barrens; Open bog; Southern sedge meadow; and Tamarack bog.

Conclusion

Crooked Lake is currently a fairly healthy, well-managed lake with many positive aspects, as discussed in this report. The main focus of continued management should include shoreland restoration, integrated management of invasive species, reduction of human-impacts on phosphorus loading, well-managed land use and continued monitoring for water quality and invasive species. Care should be taken to maintain the overall excellent quality of the lake and its surroundings and preserve its status as an Outstanding Resource.

It is hoped that the recommendations below will help in these aims.

RECOMMENDATIONS

Lake Management Plan

Crooked Lake does not currently have an approved lake management plan, but submitted a draft to the WDNR for possible approval in early 2008. Part of the delay was due to the lack of information until the conclusion of the lake classification study. It is anticipated that by the end of 2008, the Crooked Lake Association, with the assistance of the Adams County Land & Water Conservation Department, will have an approved lake management plan.

This plan will include the following aspects concerning the management of the lake (and others): aquatic plant management; control/management of invasive species; wildlife and fishery management; watershed management; shoreland protection; critical habitat protection; water quality protection.

Watershed Recommendations

Although neither the surface nor ground watershed for Crooked Lake is particularly large, results of the modeling certainly suggests that input of nutrients, especially phosphorus, are a factor that needs to be explored for Crooked Lake.

Therefore, it is recommended that both the surface and ground watersheds be inventoried, documenting any of the following: runoff from any livestock operations that may be entering the surface water; soil erosion sites; agricultural producers not complying with nutrient management plans and/or irrigation water management plans.

If such sites are documented, steps for dealing with these issues can be incorporated into the lake management plan to be completed by the end of 2008.

Shoreland Recommendations

Based on the 2005 aquatic plant survey and the 2004 shoreland survey, the following recommendations are made concerning aquatic plants and aquatic invasive species:

All lake residents should practice best management on their lake properties, including keeping septic systems cleaned and in proper condition, eliminating the use of lawn fertilizers, cleaning up pet wastes and not composting near the water.

Aquatic Plant/Aquatic Invasive Species

1) Residents should become more involved in the Citizen Lake Water Monitoring Program, Invasive Species Monitoring and Clean Boats, Clean Waters. This will allow not only noting changes in the Eurasian Watermilfoil patterns, but also help identify any new species. Noting the presence and density of these species early is the best way to take preventive action to keep them from becoming a bigger problem.

2) Lake residents should protect and increase natural shoreline in some areas of the lake around Crooked Lake. In general, disturbed shoreline sites support an aquatic plant community that is less able to resist invasions of exotic species and shows impacts from nutrient enrichment.

3) All lake users should protect the aquatic plant community in Crooked Lake.

4) The Crooked Lake Association should maintain exotic species signs at the boat landings and contact WDNR if the signs are missing or damaged.

5) The Crooked Lake Association should continue monitoring of Eurasian Watermilfoil and hand-pulling. Early-season chemical treatments may be necessary if the spread can't be stopped. Residents should be encouraged to hand-pull scattered EWM plants.

6) Consideration should be given to propagating the native weevil that attacks Eurasian Watermilfoil to assist in EWM management.

7) The Crooked Lake Association should apply for a permit to mechanically harvest the narrows area and navigation channels as needed to reduce the spread of invasives and increase the safety of boat navigation in these areas.

Critical Habitat Recommendations

There are also several recommendations appropriate for the critical habitat areas.

(1) Maintain current habitat for fish and wildlife.
(2) Do not remove fallen trees along the shoreline nor logs in the water.
(3) No alteration of littoral zone unless to improve spawning habitat.
(4) Seasonal protection of spawning habitat.
(5) Maintain snag/cavity trees for nesting.
(6) Maintain or increase wildlife corridor.
(7) Maintain sedge meadow and deep marsh areas.
(8) Maintain no-wake zone.
(9) Protect emergent vegetation for habitat and shoreline protection.
(10) Removal of submergent vegetation for navigation purposes only.
(11) Seasonal control of Eurasian Watermilfoil by using control methods specific for exotics.
(12) Minimize aquatic plant and shore plant removal to maximum 30' wide access/viewing corridor. Leave as much vegetation as possible to protect water quality and habitat.
(13) Use forestry best management practices.
(14) No use of lawn products.
(15) No bank grading or grading of adjacent land.
(16) No pier construction or other activity except by permit using a case-by-case evaluation.
(17) No installation of pea gravel or sand blankets.
(18) No bank restoration unless the erosion index scores moderate or high.
(19) If the erosion index does score moderate or high, bank restoration only using biologs or similar bioengineering, with no use of riprap or retaining walls.
(20) Placement of swimming rafts or other recreational floating devices only by permit.
(21) Maintain buffer of shoreline vegetation.
(22) Maintain aquatic vegetation in undisturbed condition for wildlife habitat, fish use and water quality protection.
(23) Post landing with exotic species alert and educational signs to prevent introduction and/or spread of exotic species.

LAKE CLASSIFICATION REPORT
FOR CROOKED LAKE, ADAMS COUNTY

INTRODUCTION

In 2003, The Adams County Land & Water Conservation Department (Adams County LWCD) determined that a significant amount of natural resource data needed to be collected on the lakes with public access in order to provide it and the public with information necessary to manage the lakes in a manner that would preserve or improve water quality and keep it appropriate for public use. In some instances, there was significant historical data about a particular lake; in that instance, the study activities concentrated on combining and updating information. In other instances, there was no information on a lake, so study activities concentrating on gathering data about that lake. Further, it was discovered that information was scattered among various citizens, so often what information was actually available regarding a particular lake was unknown. To assist in updating some information and gathering baseline information, plus centralize the data collected, so the public may access it. The Adams County LWCD received a series of grants from the Wisconsin Department of Natural Resources (WDNR) from the Lake Classification Grant Program.

Objectives of the study were:

- collect physical data on the named lakes to assist in assessing the health of Adams County lake ecosystems and in classifying the water quality of the lakes.
- collect chemical and biological data on the named lakes to assist in assessing the health of Adams County lake ecosystems and in classifying the water quality of the lakes.
- develop a library of lake information that is centrally located and accessible to the public and to City, County, State and Federal agencies.
- make specific recommendations for actions and strategies for the protection, preservation and management of the lakes and their watersheds.
- create a baseline for future lake water quality monitoring.
- Provide technical information for the development of comprehensive lake management plans for each lake
- provide a basis for the water quality component of the Adams County Land and Water Resource Management Plan. Components of the plan will be incorporated into Adams County's "Smart Growth Plan".
- develop and implement educational programs and materials to inform and education lake area property owners and lake users in Adams County.

METHODS OF DATA COLLECTION

To collect the physical data, the following methods were used:

- delineation & mapping of ground & surface watersheds using topographic maps, ground truthing and computer modeling;
- identification of flow patterns for both the surface & ground watersheds using known flow maps and topographic maps;
- inventory & mapping of current land use with orthographic photos and collected county information;
- inventory & mapping of shoreline erosion and buffers using county parcel maps and visual observation;
- inventory & mapping for historical and cultural sites using information from the local historical society and the Wisconsin Historical Society;
- identification & mapping of critical habitat areas with WDNR and Adams County LWCD staff;
- identification & mapping of endangered or threatened natural resources (including natural communities, plant & animal species) using information from the Natural Heritage Inventory of Wisconsin;
- identification & mapping of wetland areas using WDNR and Natural Resource Conservation Service wetland maps;
- preparation of soil maps for each of the lake watersheds using soil survey data from the Natural Resource Conservation Service.

To collect water quality information, different methods were used:

- for three years, lakes were sampled during late winter, at spring and fall turnover, and several times during the summer for various parameters of water quality, including dissolved oxygen, relevant to fish survival and total phosphorus, related to aquatic plant and algae growth;
- random samples from wells in each lake watershed were taken in two years and tested for several factors;
- aquatic plant surveys were done on all 20 lakes and reports prepared, including identification of exotics, identifying existing aquatic plant community, evaluation of community measures, mapping of plant distribution, and recommendations;
- all lakes were evaluated for critical habitat areas, with reports and recommendations being made to the respective lakes and the WDNR;
- lake water quality modeling was done using data collected, as well as historical data where it was available.

WATER QUALITY COMPUTER MODELING

Wisconsin developed a computer modeling program called WiLMS (Wisconsin Lake Modeling Suite) to assist in determining the amount of phosphorus being loaded annually into a lake, as well as the probable source of that phosphorus. This suite has many models, including Lake Total Phosphorus Prediction, Lake Eutrophic Analysis Procedure, Expanded Trophic Response, Summary Trophic Response, Internal Load Estimator, Prediction & Uncertainty Analysis, and Water & Nutrient Outflow. The models that various types of data inputs: known water chemistry; surface area of lake; mean depth of lake; volume of lake; land use types & acreage. This information is then used in the various models to determine the hydrologic budget, estimated residence time, flushing rate, and other parameters.

Using the data collected over the course of the studies, various models were run under the WiLMS Suite. These water quality models are computer-based mathematical models that simulate lake water quality and watershed runoff conditions. They are meant to be a tool to assist in predicting changes in water quality when watershed management activities are simulated. For example, a model might estimate how much water quality improvement would occur if watershed sources of phosphorus inputs were reduced. However, it should be understood that these models predict only a relative response, not an exact response. Modeling results will be incorporated into topic discussions as appropriate.

DISSEMINATION OF PROJECT DELIVERABLES

The results of this study will be distributed various agencies, organizations and the public as previously described. Based on the classification information, the Adams County Land and Water Conservation Department will identify assistance requests and determine the appropriate future activities, based on the classification determinations. To provide the requested assistance, Adams County Land and Water Conservation Department will incorporate the lake management plans goals, priorities and action items into its Annual Plan of Operations. Goals, priorities and action items may include educational programs, formation of lake districts, further development of lake management plans and implementation of lake management plans.

ADAMS COUNTY INFORMATION

Adams County lies in south central Wisconsin, shaped roughly like the outline of Illinois. Adams County is a small rural county with a full-time population of about 20,000. Between 1980 and 2000, Adams County's population grew by more than 20%, with most of the population increase being located upon the lakes and streams. The population increase has resulted in a greater need for facilitation, technical assistance and education, including information on the lakes and streams.

Figure 1: Adams County Location in Wisconsin

CROOKED LAKE BACKGROUND INFORMATION

Crooked Lake is a 48-acre natural seepage lake located in the Town of Jackson, Adams County, in the Central Sands Area of Wisconsin. A "seepage lake" is a natural lake with no natural stream inlet or outlet and fed by precipitation, runoff and groundwater. It is one of many lakes in the Town of Jackson, most of which are seepage lakes similar to Crooked Lake (see arrow below pointing to location of Crooked Lake in the Town of Jackson).

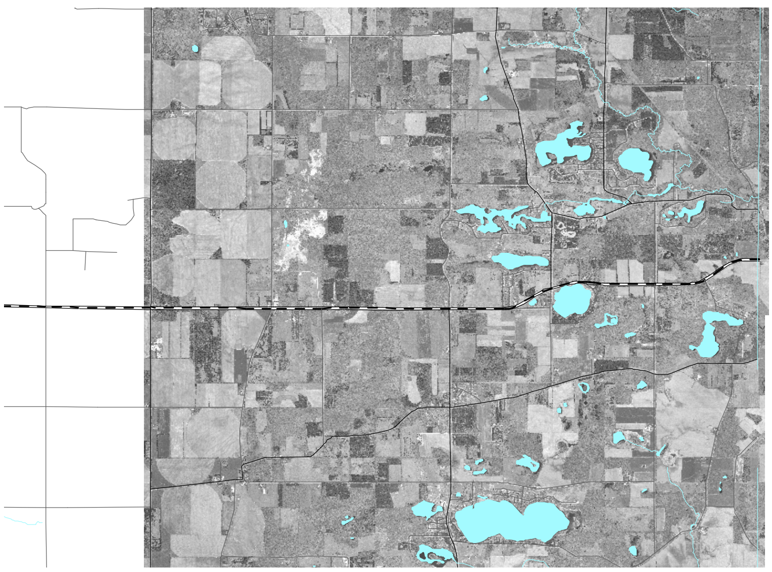

Figure 2: CROOKED LAKE location

Crooked Lake is part of the Neenah Creek Watershed, a large watershed of 182 square miles which flows into the Fox River and eventually into Lake Michigan. The Central Sand Hills, which contain Crooked Lake, are an ecological landscape (a recessional moraine) on the eastern edge of what was Glacial Lake Wisconsin. The area is characterized by glacial moraines and glacial outwash, as well as the kettle holes that formed natural lakes—such as Crooked Lake. Elevations average between 900 to 1000 feet above sea level.

Archeological Sites

There are many Native American archeological sites in Adams County, with four located right around Crooked Lake, including two burial mound groups. Under the federal act on Native American burials, these sites cannot be further disturbed without permission of the federal government and input from the local tribes.

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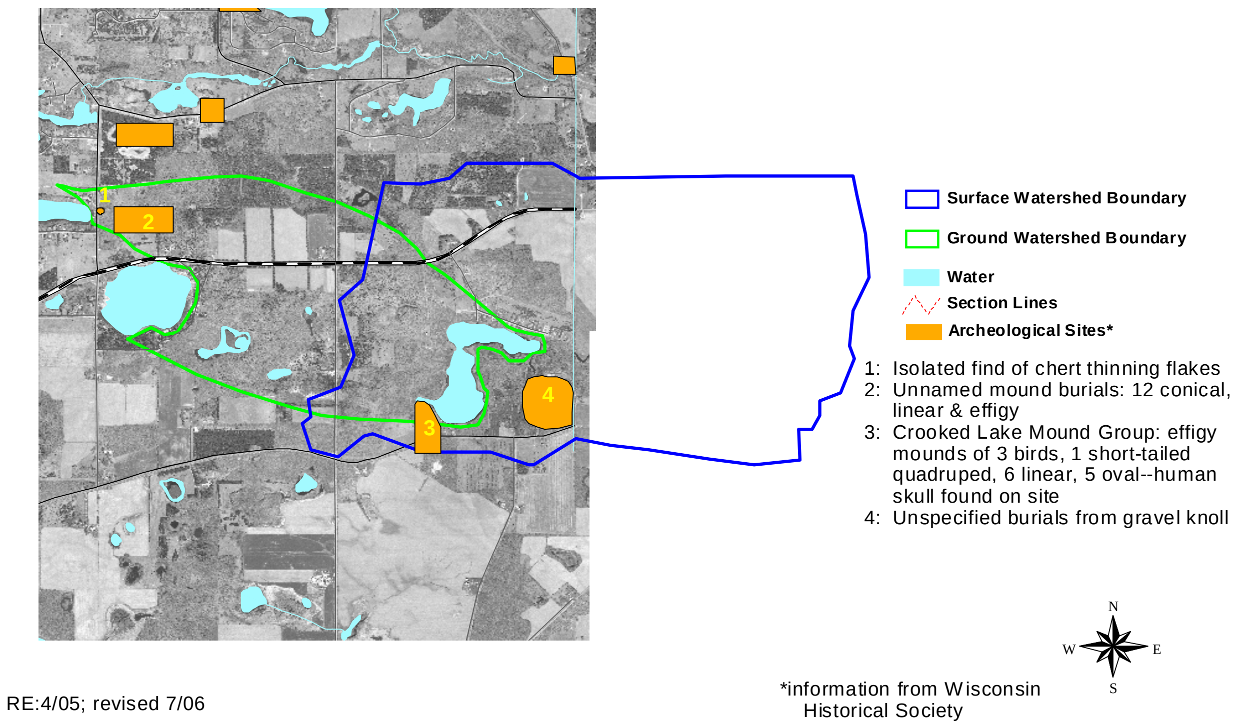
Figure 3: Crooked Lake Archeological Sites



Bedrock and Historical Vegetation

Bedrock around Crooked Lake is mostly sandstone, with pockets of dolomite and shale, formed in the Cambrian Period of Geology (542 to 488 millions years ago). Bedrock is generally 50’ to 100’ down from the land surface. The water table in most areas around Crooked Lake is fairly near the surface.

Original upland vegetation of the area around Crooked Lake included oak-forest, oak savanna, pine barrens and tallgrass prairie. Wetland areas were also common, including wet-mesic prairies, wet prairie, coastal plain marshes and fen. Hills and kettles created by glacial deposits make up the southeast area of Adams County, where Crooked Lake is located.

Soils in the Crooked Lake Watersheds

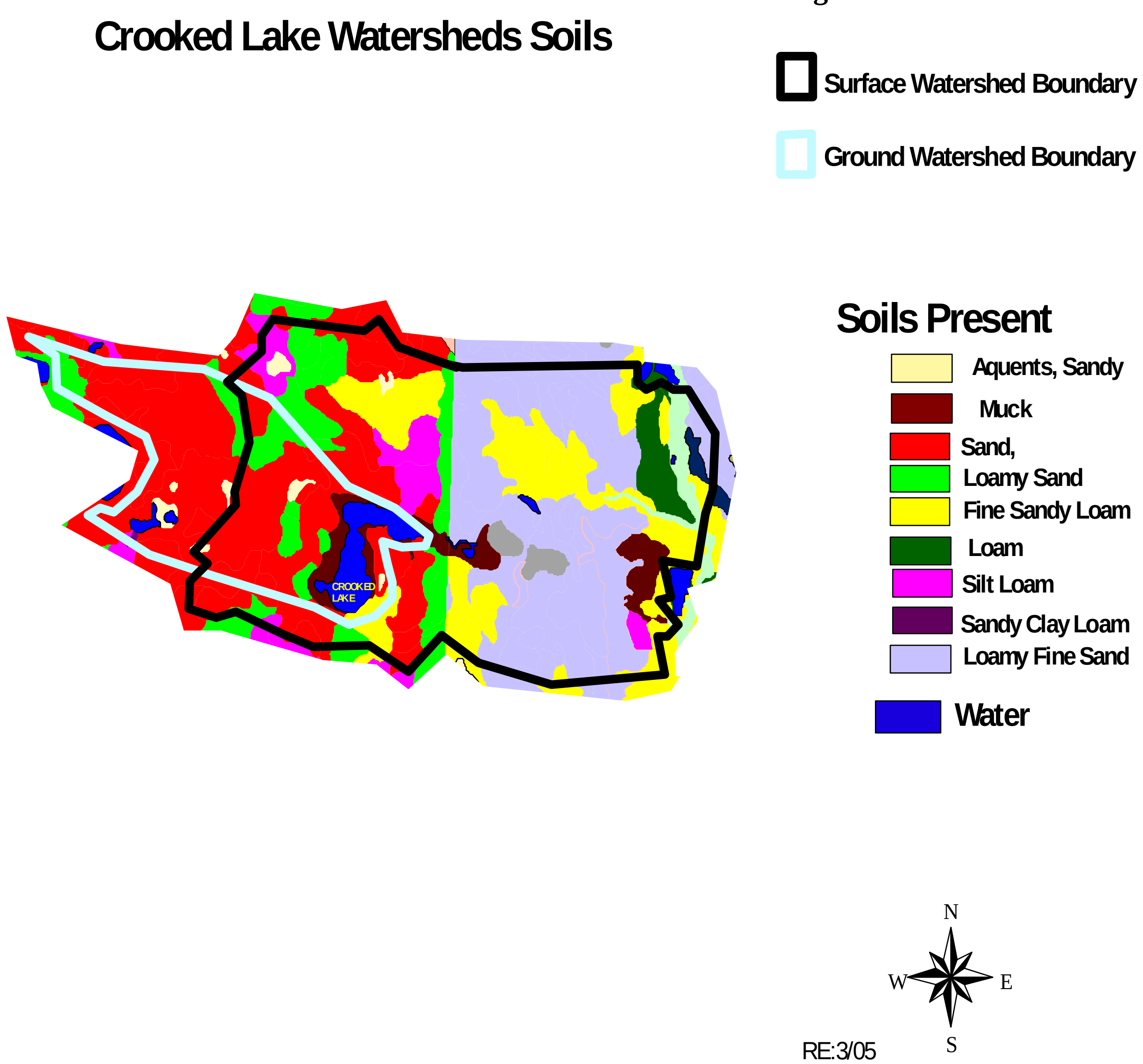
Except for some pockets of muck and silt loam, the dominant soils in the surface watershed for Crooked Lake are loamy fine sand and fine sandy loam, with slopes from very flat up to 25%. Sandy soils dominate the ground watershed, followed by loamy sand.

Sandy soils tend to be excessively drained, no matter what the slope. Water, air and nutrients move through sandy soils at a rapid rate, so that little runoff occurs unless the soil becomes saturated. Although water erosion can be a problem, wind erosion may be more of a hazard with sandy soils, especially since they dry out so quickly. There are also draught hazards with sandy soils. Getting vegetation started in sandy soils is often difficult due to the low available water capacity, as well as low natural fertility and organic material. Onsite waste disposal in sandy soils is also a problem because of slope and seepage; mound systems are usually required.

Loamy sands and sandy loams tend to be well-drained, with water, air and nutrients moving through them at a rapid rate. Runoff, when it occurs, tends to be slow. Loamy sands have little water-holding capacity and low natural fertility, although they usually have more organic matter present than do sandy soils. Both wind and water erosion are potential hazards with loamy sands, as is draught. The same difficulties with waste disposal and vegetation establishment are present with loamy sands as with sandy soils.

The soil and soil slopes around lakes and streams are very important to water quality. They affect amount of infiltration of surface precipitation into the ground and the amount of contaminants that may reach the groundwater, as well as the amount of surface stormwater runoff. In addition, these two factors affect the amount and content of pollutants and particles (including soil) that may wash into a water body, affecting its water quality, its aquatic plant community and its fishery. Further, soil types and soil slopes help determine the appropriate private sewage system and other engineering practices for a particular site, since they affect absorption, filtration and infiltration of contamination from engineering practices.

Figure 4



CURRENT LAND USE

Both the surface and ground watersheds of Crooked Lake are fairly small, as seen in the map and table below. The most common current land uses in the Crooked Lake Surface Watershed are non-irrigated agriculture and woodlands. In the ground watershed, woodlands dominate (See Figures 5, 6a, 6b & 7).

Figure 5: Crooked Lake Watersheds Land Use in Acres and Percent of Total

	Surface		Ground		Total	
Crooked Lake	**Acres**	**% of Total**	**Acres**	**% of Total**	**Acres**	**% of Total**
Agriculture--Non Irrigated	735	47.50%	142.89	22.29%	877.89	40.12%
Government	3.56	0.23%	0	0.00%	3.56	0.16%
Residential	202.55	13.09%	104.45	16.29%	307	14.03%
Water	58.8	3.80%	71.4	11.14%	130.2	5.95%
Woodland	547.58	35.38%	322.26	50.28%	869.84	39.74%
total	1547.37	100.00%	641	100.00%	2188.37	100.00%

Studies have shown that land use around a lake has a great impact on the water quality of that lake, especially in the amount and content of surface runoff. (James, T., 1992, I-10; Kibler, D.F., ed. 1982. 271) For example, while natural woodland may (on the average) absorb 3.5" out of a 4" rainfall, leaving only .5" as runoff, a residential area with quarter-acre lots may absorb only 2.3" of the 4", leaving 1.7" to run off the land into the lake—the same amount as may be expected to run off from a corn or soybean field. 1.7" of runoff translates into 46,200 gallons per acre ending up in the lake! Percentage of impervious surface, the soil type, vegetation present and slope of the site can all affect runoff volume. (Frankenberger, J, ID-230).

Figure 6a: Land Use in Crooked Lake Surface Watershed

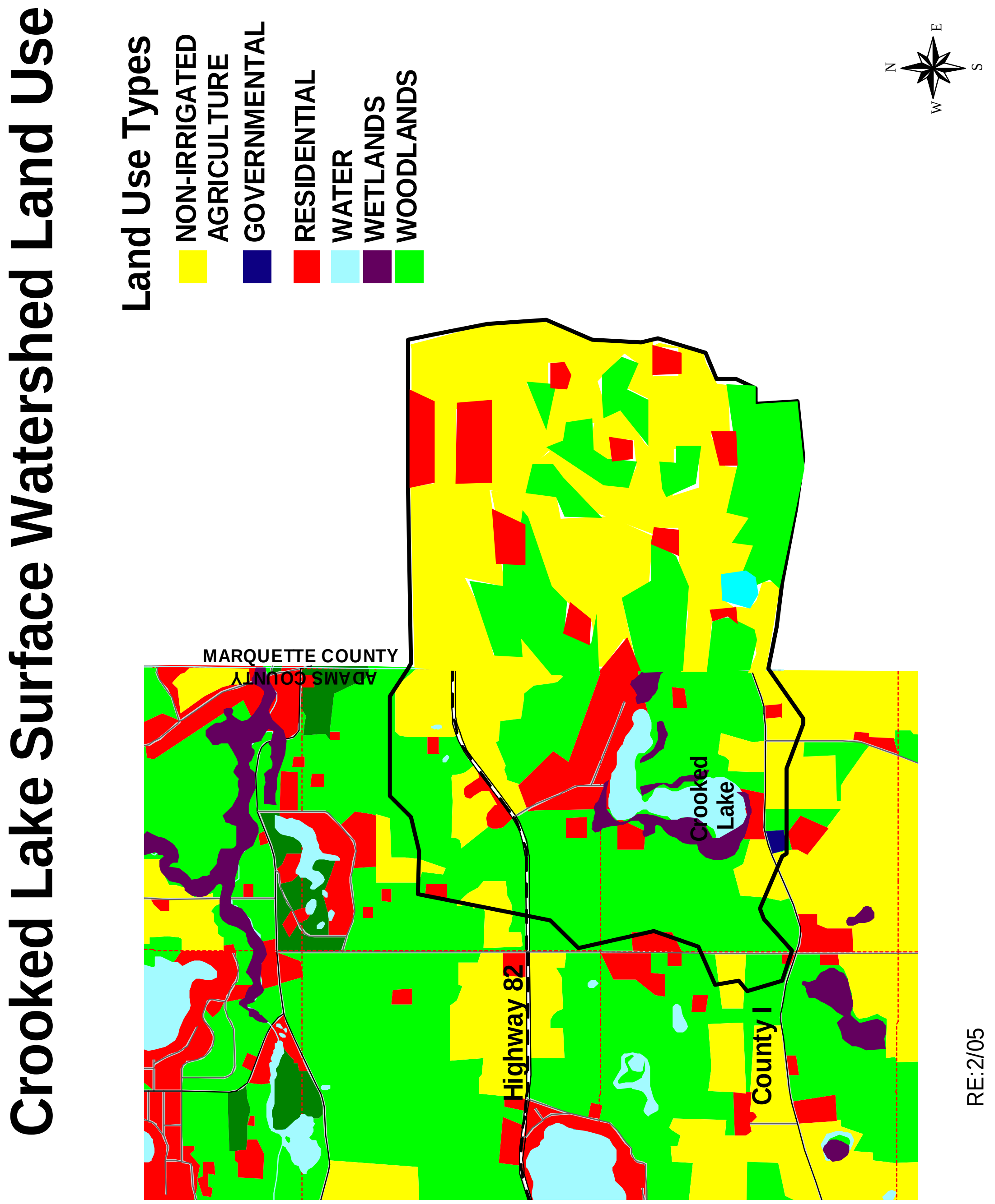
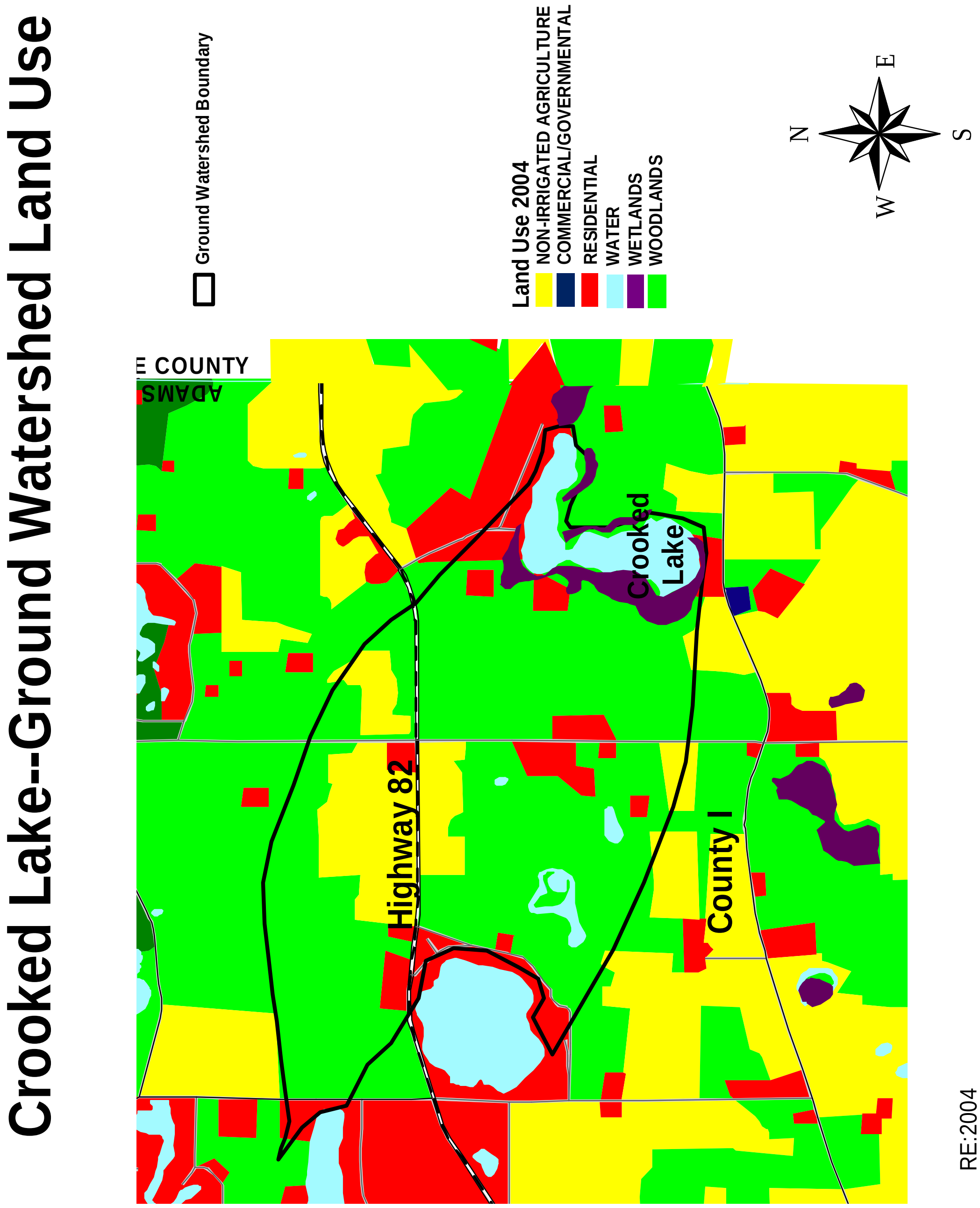
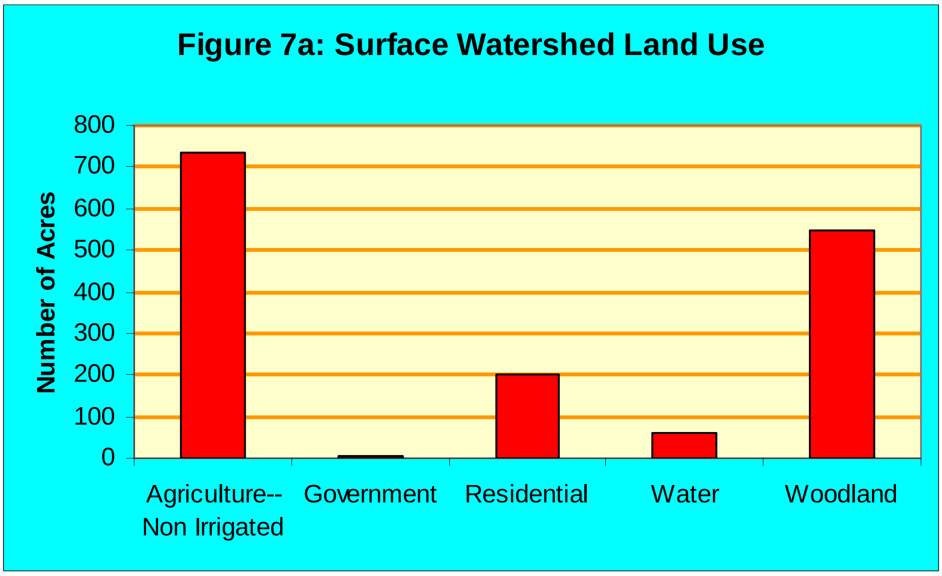
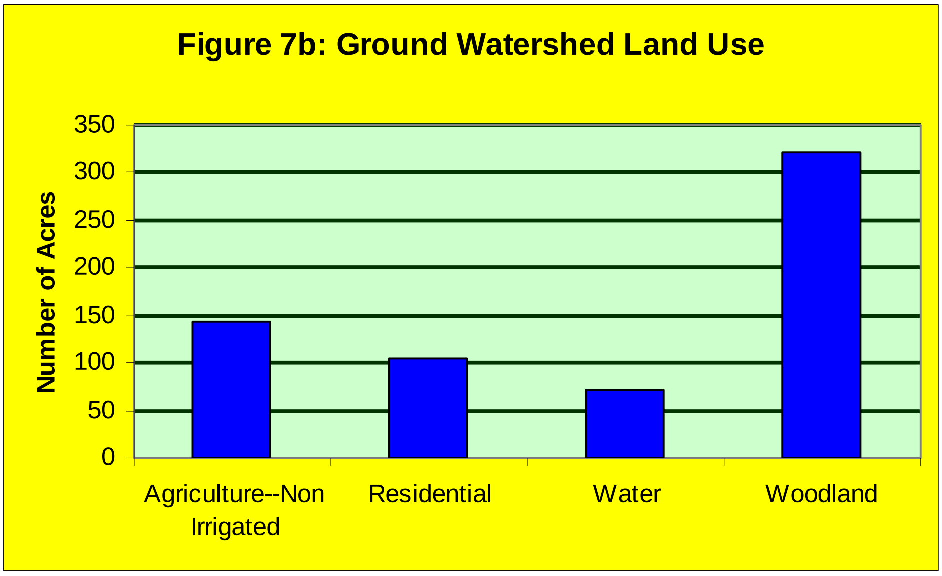


Figure 6b: Land use in Crooked Lake Ground Watershed



When water runs over a surface, it picks up whatever loose pollutants—sediment, chemicals, metals, exhaust gas, etc—are present on that surface and takes those items with it into the lake. Increased development around a lake tends to increase the amount of pollutants being carried into the lake, thus negatively affecting water quality. Residential development areas with lots of one-quarter acre or less may deliver as much as 2.5 pounds of phosphorus per year to the lake for each acre of development.





There are two specific kinds of land use—wetlands and shorelands--that are so important to water quality that they will be separately discussed.

WETLANDS

A number of wetlands are located in the Crooked Lake surface and ground watersheds (Figures 6a & 6b). In the past, wetlands were seen as "wasted land" that only encouraged disease-transmitting insects. Many wetlands were drained and filled in for cropping, pasturing, or even residential development. In the last few decades, however, the importance of wetlands has become evident, even as wetlands continue to decline in acreage.

Wetlands play an important role in maintaining water quality by trapping many pollutants in runoff and flood waters, thus often helping keep clean the water they connect to. They serve as buffers to catch and control what would otherwise be uncontrolled water and pollutants. Wetlands also play an essential role in the aquatic food chain (thus affecting fishery and water recreation), as well as serving as spaces for wildlife habitat, wildlife reproduction and nesting, and wildlife food.

Figure 8: Crooked Lake shore wetland

The photo in Figure 8 shows one of the wetlands along the shore of Crooked Lake. Looking at the map of wetlands directly around Crooked Lake (see Figure 9) makes it evident how important wetlands are to Crooked Lake…more than 1/3 of the lake has wetlands at or near the shore that serve as filters and trappers that help keep the lake as clean as it is. It is essential to preserve these wetlands for the health of Crooked Lake.

Figure 9: Wetlands at Crooked Lake

Figure 10: Other Crooked Lake Shore Wetlands

SHORELANDS

Crooked Lake has a total shoreline of 2.22 miles (11721.60) feet). Much of the shore has been left unaltered and includes many types of wetlands. Areas on the south side of the lake are steeply sloped. Any buildings are generally located 70 or more feet back from the shore. The shore consists of privately-owned lots and a boat ramp on the north side of the lake owned by the Adams County Parks Department.

The Adams County Land & Water Conservation Department conducted a survey of the Crooked Lake shoreline in 2004. Shore types were categorized as "armored" and "vegetated". "Vegetated" shores encompassed both native vegetation of any type and mowed lawns. 93% of Crooked Lake's shoreline is naturally vegetated. The remaining 6% is mowed lawn.

Figure 11: Shoreline of Crooked Lake (2004)

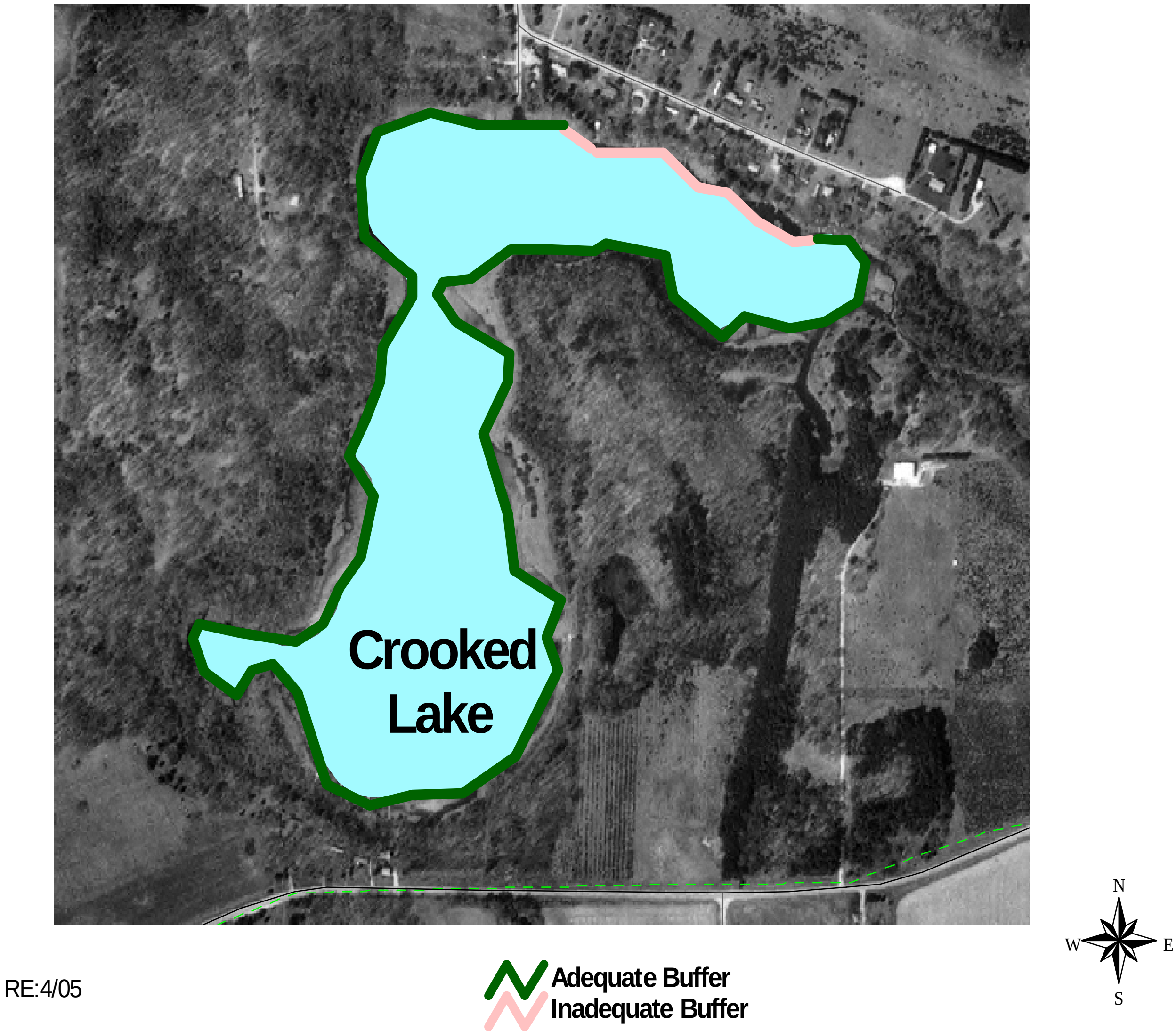
Under the Adams County Shoreland Ordinance, the first 35 feet landward from the water is a “buffer.” Shoreland buffers are an important part of lake protection and restoration. These buffers are simply a wide border of native plants, grasses, shrubs and trees that filter and trap soil & similar sediments, fertilizer, grass clippings, stormwater runoff and other potential pollutants, keeping them out of the lake. A 1990 study of Wisconsin shorelines revealed that a buffer of native vegetation traps 5 to 18 times more volume of potential pollutants than does a developed, traditional lawn or hard-armored shore.

The 2004 inventory included classifying areas of the Crooked Lake shorelines as having “adequate” or “inadequate” buffers. An “adequate” buffer was defined as one having the first 35 feet landward covered by native vegetation. An “inadequate” buffer was anything that didn’t meet the definition of “adequate buffer”, including native vegetation strips less than 35 feet landward. Using these definitions, 83.72% (about 9813.6 feet) of Crooked Lake’s shoreline had an “adequate buffer”, leaving 16.28% (1908) as “inadequate.” Most of the “inadequate” buffer areas were found with traditional mowed lawns and/or insufficient native vegetation at the shoreline to cover 35 feet landward from the water line.

Vegetated shoreland buffers help stabilize shoreline banks, thus reducing bank erosion. The plant roots give structure to the bank and also increase water infiltration and decrease runoff. A vegetated shore is especially important when shores are steep and soft, as are many of the Crooked Lake shores. Figure 12 maps the adequate and inadequate buffers on Crooked Lake.

Lakeside buffers also serve as important habitat. Lake edges usually contain aquatic and wetland plants, grading into drier groundcover, then shrubs and trees as one moves inland towards drier land. Buffers provide habitat for many species of water-dependent wildlife, including furbearers, reptiles, birds and insects. Many wildlife species, including birds, small mammals, fish & turtles breed, nest, forage and/or perch in shore buffer areas. Further, 80% of the endangered and threatened species listed spend part of their life in this near-lake buffer area. (Wagner et al, 2006)

Figure 12: Buffer Categories on Crooked Lake



When the natural shoreline is replaced by traditional mowed turf-grass lawns, rock, wooden walls or similar installments, bird and animal life, land-based insects, and aquatic insects that hatch or winter on natural shore are negatively impacted. For example, on many Adams County lakes, the non-native aquatic plant, Eurasian Watermilfoil has invaded. There is a weevil native to Wisconsin that weakens Eurasian Watermilfoil by burrowing into and developing within its stems, but that weevil depends on a native-plant shore to overwinter. If the shore is instead covered by rock, seawall or traditional lawn, these weevils will be unavailable for the lake to use as Eurasian Watermilfoil control.

The filtering process and bank stabilization that buffers provide help improve a lake's water quality, including water clarity. Studies in Minnesota, Maine and Michigan have shown that waterfront property value increases for every foot the water clarity of a lake increases. (Krysel et al, 2003).

Natural shoreland buffers serve important cultural functions. They enhance the lake's aesethics. Studies have shown that aeshetics rank high as one of the reasons people visit or live on lakes. Shore buffers can provide visual & audio privacy screens for homeowners from other neighbors and/or lake users.

Adequate buffers on Crooked Lake could be easily installed on most of the lake by either letting the first 35 feet landward from the water just grow without mowing it, except for a path to the water, or—if something more controlled or aesthetically pleasing was desired—by planting native seedlings sufficient to fill in the first 35 feet.

WATER QUALITY

Between 2004 and 2006, Adams County Land & Water Conservation Department gathered water chemistry and other water quality information on 20 lakes in Adams County with public access. Crooked Lake was one of these lakes. Part of the information was gained from periodic water sampling done by Adams County LWCD. Historic information about water testing on Crooked Lake was also obtained from the WDNR (1992).

Phosphorus

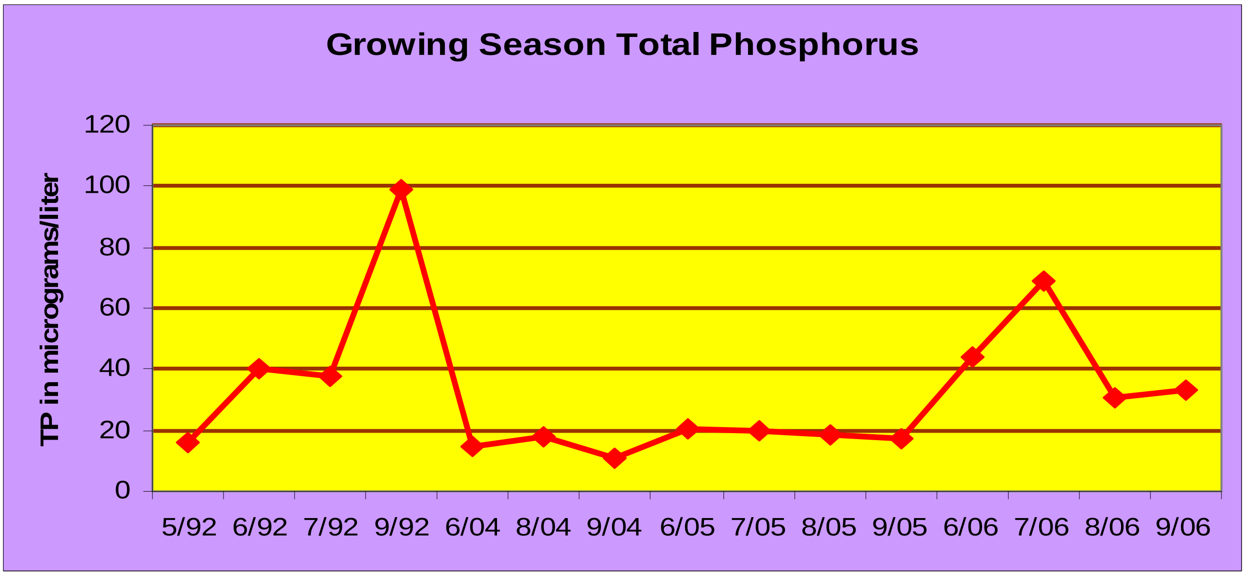
Most lakes in Wisconsin, including Crooked Lake, are phosphorus-limited lakes: of the pollutants that end up in the lake, the one that most affects the overall quality of the lake water is phosphorus. The amount of phosphorus especially affects the frequency and density of aquatic vegetation and the frequency and density of various kinds of algae, as well as water clarity and other quality aspects. One pound of phosphorus can produce as much as 500 pounds of algae.

Phosphorus is not an element that occurs in high concentration naturally, so any lake that has significant phosphorus readings must have gotten that phosphorus from outside the lake or from internal loading. Some phosphorus is deposited onto the lake from atmospheric deposition, especially from soil or other particles in the air carrying phosphorus. A lake that includes a flooded wetland area may have a significant amount of phosphorus being released during the flushing of the wetland area. Phosphorus may accumulate in sediments from dying animals, dying aquatic plants and dying algae. If the bottom of the lake becomes anoxic (oxygen-depleted) or hypoxic (low oxygen), chemical reactions may cause phosphorus to be released into the water column.

Although there are several forms of phosphorus in water, the total phosphorus (TP) concentration is considered a good indicator of a lake's nutrient status, since the TP concentration tends to be more stable than other types of phosphorus concentration. For a natural lake like Crooked Lake, a total phosphorus concentration below 20 micrograms/liter tends to reduce nuisance algal blooms. Crooked Lake's growing season (June-September) surface average total phosphorus level of 17.3 micrograms/liter is low enough so that nuisance algal blooms should occur only rarely.

The limiting factor in most Wisconsin lakes, including Crooked Lake, is phosphorus. Measuring the phosphorus in a lake system thus provides an indication of the nutrient level in a lake. Increased phosphorus in a lake will feed algal blooms and also may cause excess plant growth. The 2004-2006 summer average phosphorus concentration in Crooked Lake was 18.8 micrograms/liter. This is below the 25 micrograms/liter average for natural lakes in Wisconsin. This concentration suggests that Crooked Lake is likely to have few nuisance algal blooms. This places Crooked Lake in the "good" level for phosphorus.

Figure 13: Summer Epilimnetic Total Phosphorus Averages in Crooked Lake



However, a comparison of the average summer phosphorus level in the lower depths of Crooked Lake (50' and deeper) to the upper depths (surface) shows that phosphorus concentrations in the lower levels of Crooked Lake are more than two times higher in the growing season than those from the upper layers of water. This suggests that the lower water depths may be accumulating phosphorus, added to that accumulating in the sediments. This situation should be monitored

As the above graph (Figure 13) indicates, the recent growing season total phosphorus levels have varied, but stayed below the 20 micrograms/milliliter recommended to avoid nuisance algal blooms, except in 2006, which had a very hot dry summer. Still, considering that the overall line since 1997 has been showing mostly increased total phosphorus levels for the growing season, phosphorus should continue to be monitored.

In most lakes in Wisconsin, phosphorus concentration in the bottom sediments of the lake is considerably higher than the concentration in the water column itself. Bottom sediments can "bind up" phosphorus, making it unavailable for aquatic plants or algae to use. Some sediment types hold phosphorus at a higher rate than others.

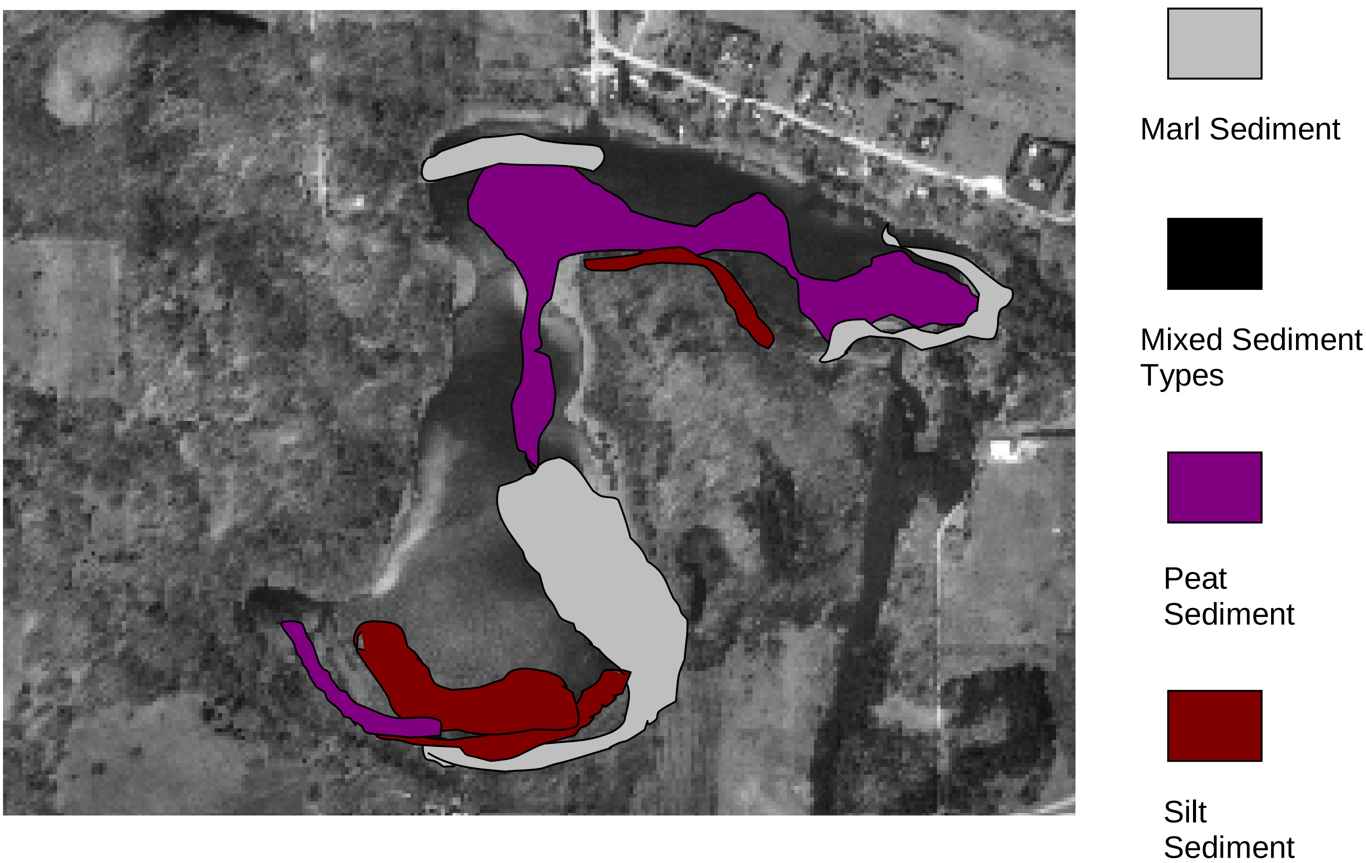


Figure 14: Sediment Map of Crooked Lake

As can be seen on the sediment map (Figure 14), some of the bottom of Crooked Lake is marl sediment. “Marl” is a calcium carbonate precipitate (solid) that forms in hardwater lakes when both calcium and pH levels are high. Marl can be good for a lake because it has a high capacity to bind phosphorus, as well as other nutrients. With such a large amount of marl sediment, Crooked Lake may benefit from it removing phosphorus from water column, thus making it unavailable for algal and aquatic plant growth.

How much a marl sediment affects aquatic plant and algal growth will depend on where the marl sediment is located, i.e., if the aquatic plants are rooted in the marl, so that they can still draw phosphorus from it, the presence of marl may not reduce aquatic plant growth. Effect will also depend on how much phosphorus the marl has already absorbed. In 80% of Wisconsin’s lakes, phosphorus is the key nutrient that determines the amount of algae and aquatic plant growth. Since much of the marl in Crooked Lake is in the deeper areas of the lake, the marl sediment probably offers more protection against nuisance algal growth than aquatic plant growth.

Groundwater testing of various wells around Crooked Lake was done by Adams County LWCD and included a test one year (2006) for total phosphorus levels in the groundwater coming into the lake. The average TP level in the wells tested was 12.2 micrograms/liter, somewhat lower than the lake surface water results. This phosphorus may also seep into Crooked Lake, although if the level is always that low, it wouldn’t be a significant contributor of phosphorus.

Land use plays a major role in phosphorus loading. A key component of the computer models used is the phosphorus budget, that is, the estimated amount of phosphorus delivered to the lake from each land use type annually. The land uses that contribute the most phosphorus are non-irrigated agriculture and residences. Using the current land use data, as well as phosphorus readings from 2004 through 2006 water sampling, a phosphorus loading prediction model was run for Crooked Lake. The current results are shown in Figure 15.

Figure 15: Current Phosphorus Loading by Land Use

PHOSPHORUS LOADING	Most	Likely
Land Use Type	**lb/yr**	**% total load**
Non-Point Sources		
Non-Irrigated Agriculture	261.8	74.0%
Residential	6.6	2.0%
Woodlands	22.0	6.2%
Government	2.2	0.1%
Groundwatershed	28.6	8.1%
Lake Surface	8.8	2.2%
Septic Systems	26.1	7.4%
total loading in pounds/year	356.1	100.0%

Phosphorus deposits such as that from flooded wetlands or from atmospheric deposition cannot be controlled by humans. However, some phosphorus (and other nutrient) input can be decreased or increased by changes in human land use patterns. Practices such as shoreland buffer restoration; infiltrating stormwater runoff from roof tops, driveways and other impervious surfaces; using no phosphorus lawn fertilizers; and reducing phosphorus input to and properly managing septic systems will minimize phosphorus inputs into the lake. Circumstances such as increased impervious surface, lawns mowed to water's edge, disturbance of shore areas, improperly-functioning septic systems and removal of native vegetation can greatly increase the volume and content of runoff—and thus increase the volume of phosphorus entering the lake. Many of these practices can also increase the concentration of phosphorus entering the lake, by runoff or other methods of entry.

The models were run using not only the current known phosphorus readings in the lake, but also representing decreases or increases of human-controlled phosphorus input by 10%, 25%, and 50%. The figures may not seem like much---until you calculate that one pound of phosphorus can result in up to 500 pounds of algae. A 10% reduction in these three areas could result in 16140 pounds less of algae per year!

Figure 16: Impact of Changes in Overall Phosphorus Input

Land Use Type	-10%	-25%	-50%
Non-Point Sources			
Non-Irrigated Agriculture	235.62	196.35	130.90
Residential	5.94	4.95	3.30
Woodlands	22	22.00	22.00
Government	2.2	2.20	2.20
Groundwatershed	25.74	21.45	14.30
Lake Surface	8.8	8.80	8.80
Septic Systems	23.52	19.60	13.07
total loading in pounds/year	323.82	275.35	194.57

Looking at this issue in terms of how much phosphorus readings in the lake might change, based on the computer modeling, in-lake perhaps makes it clearer. Figure 16 shows that the effect of 10% and 25% decrease to human-impacted phosphorus within the lake.

Reducing the amount of input from the surface and ground watersheds results in less nutrient loading into the lake itself. Under the modeling predictions, reducing phosphorus inputs from human-based activities even 10% could improve Crooked Lake water quality by up to 4 micrograms of phosphorus/liter; a 25% reduction could save up to 11 micrograms/liter (see Figure 17). Currently, both the spring turnover and summer phosphorus levels are below the threshold value of 20 micrograms/liter, but a phosphorus increase from human activities of only 25% would put the phosphorus levels in the lake over that threshold in the summer. The result would be more algal blooms and more aquatic plants. Decreases would reduce those problems.

These predictions make it clear that reducing current phosphorus inputs to the lake are essential to improve, maintain and protect Crooked Lake's health for future generations.

Figure 17: In-Lake Impact of Phosphorus Reduction

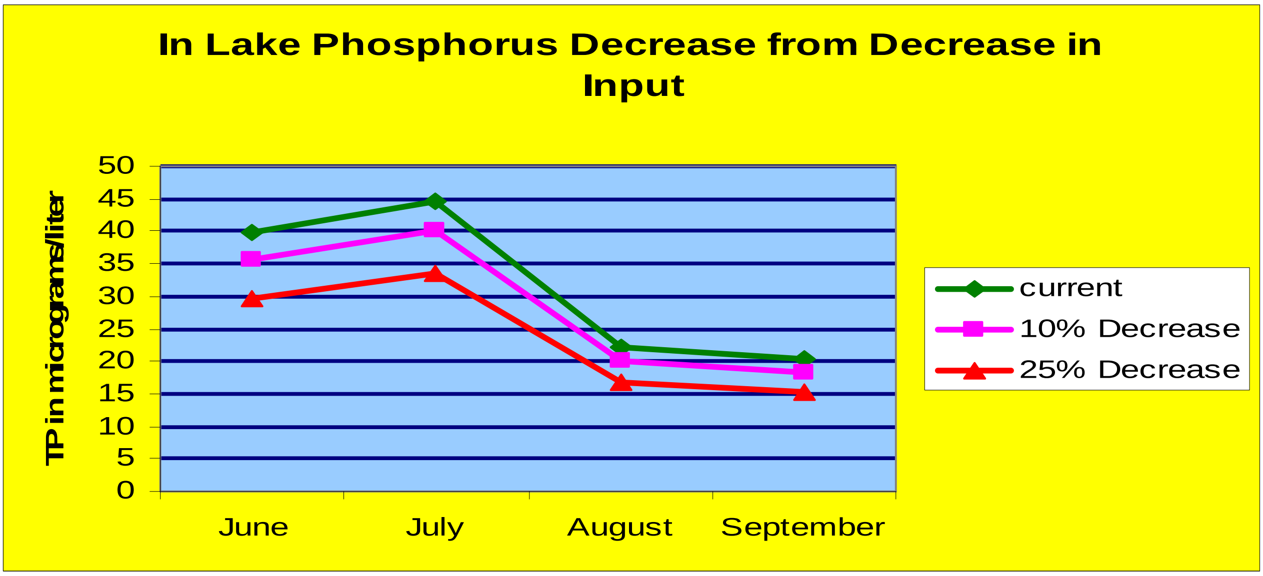


Figure 18: Photo of a Lake with Algal Bloom

Water Clarity

Water clarity is a critical factor for plants. If plants don't get more than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. Average summer Secchi disk clarity in Crooked Lake in 2004-2006 was 10.6 feet. This is very good water clarity, putting Crooked Lake into the "oligotrophic" category for water clarity. Records since 1990 show that the water clarity in Crooked Lake has consistently remained high (see Figure 19).

Figure 19: Average Summer Secchi Disk Readings in Crooked Lake

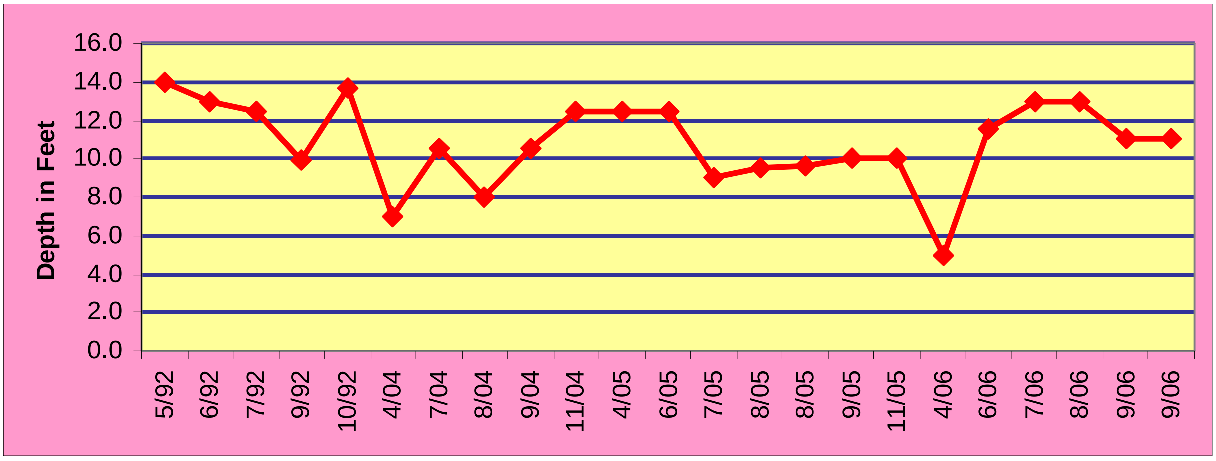


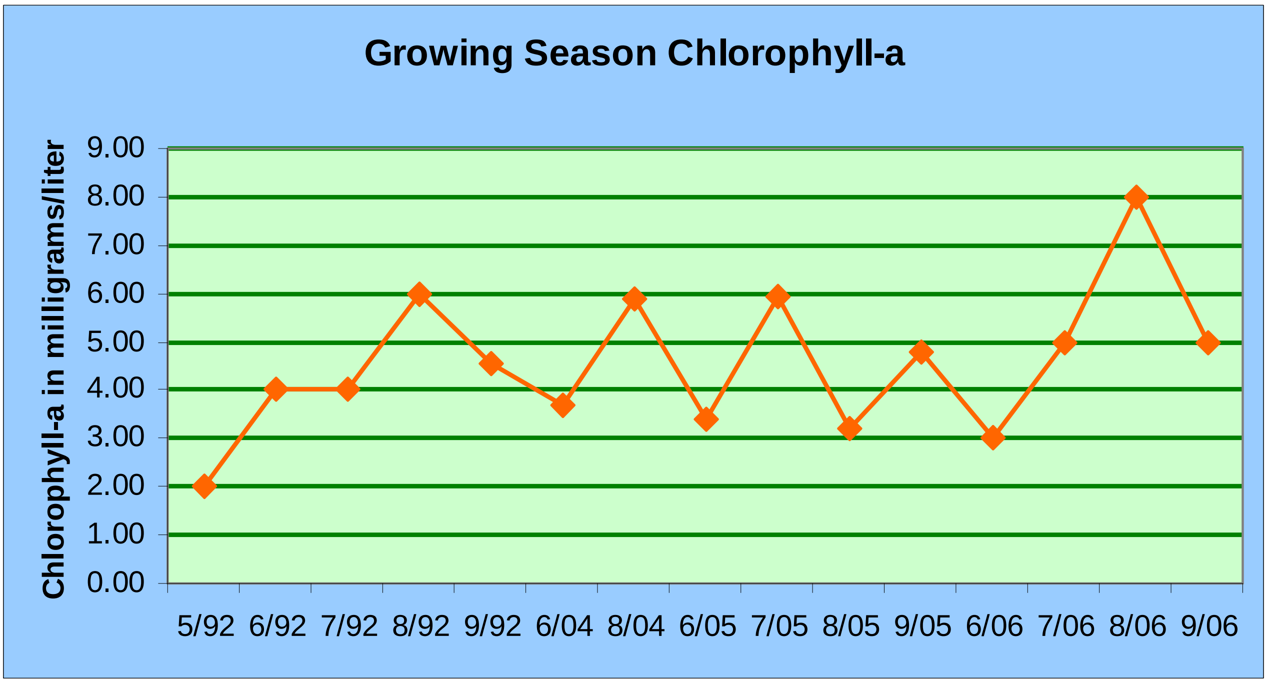
Figure 20: Photo of Testing Water Clarity with Secchi Disk

Chlorophyll a

Chlorophyll-a concentrations provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth, as well as result in unpleasing odor and appearance. Studies have shown that the amount of chlorophyll a in lake water depends greatly on the amount of algae present; therefore, chlorophyll-a levels are commonly used as a water quality indicator. The 2004-2006 summer (June-September) average chlorophyll concentration in Crooked Lake was 4.4 milligrams/liter. This low algae concentration places Crooked Lake at the "oligotrophic" level for chlorophyll a results.

Chlorophyll-a averages have stayed low since 1992, the first year for which records were found, and have remained very low between 2004 and 2006, when the Adams County LWCD was monitoring the lake.

Figure 21: Summer Chlorophyll-a Averages

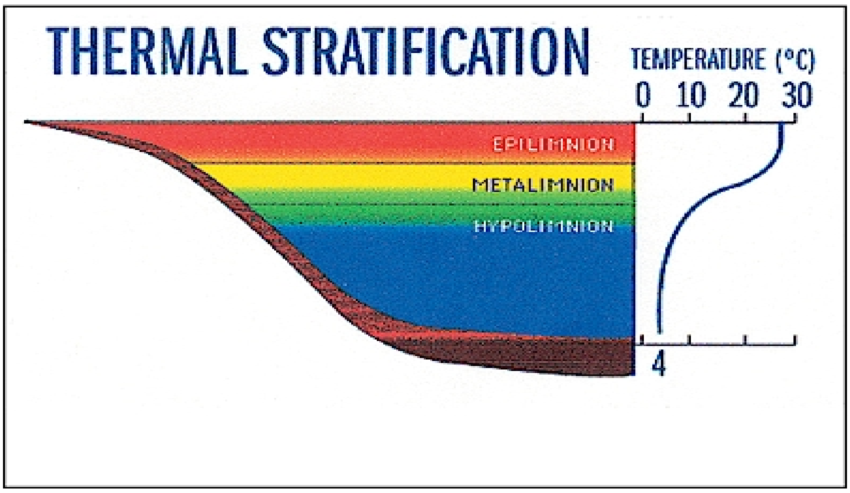


Dissolved Oxygen

Oxygen dissolved in the water is essential to all aerobic aquatic organisms. The oxygen in a lake comes from the atmosphere and from the process of photosynthesis. Aquatic plants and algae consume carbon dioxide and respirate oxygen back into the lake water. The distribution of oxygen within a lake is affected by many factors, including water circulation, water stratification, winds or storms, air temperature; water temperature, nutrient availability, and the density and location of algae and/or aquatic plants.

Oxygen consumption in the sediment and the water just above it (hypolimnion) is more sensitive that those in the two upper layers of water (metalimnion and epilimnion) because the bottom consumption is less likely to be balanced by the circulation and photosynthesis output available to the upper layers.

Figure 22: Lake Stratification Layers



Low oxygen during the summer in the bottom waters of a lake occurs naturally as oxygen in the bottom layer is consumed, but not replenished. It is common that as the summer progresses, the oxygen concentration of the bottom waters decreases. In Crooked Lake, there were hypoxic periods in the depths from 20’ to 50’ during the summers of 2004 and 2005. By end of summer 2005 (August), dissolved oxygen concentration at 20’ depth was only 3.8 mg/l and 2.9 mg/l at the 50’ depth. And in 2004, by September, dissolved oxygen concentration at 20’ down was only 1.8 mg/l and 1.7 mg/l at 50’ depth. This pattern was not present in 2006 when oxygen levels at all depths were over 5 mg/l (the minimum level for most fish survival).

The charts (Figures 23a, b, c) below show the annual (2004-2006) variations in dissolved oxygen levels in milligrams/liter, depth in feet and months of the year:

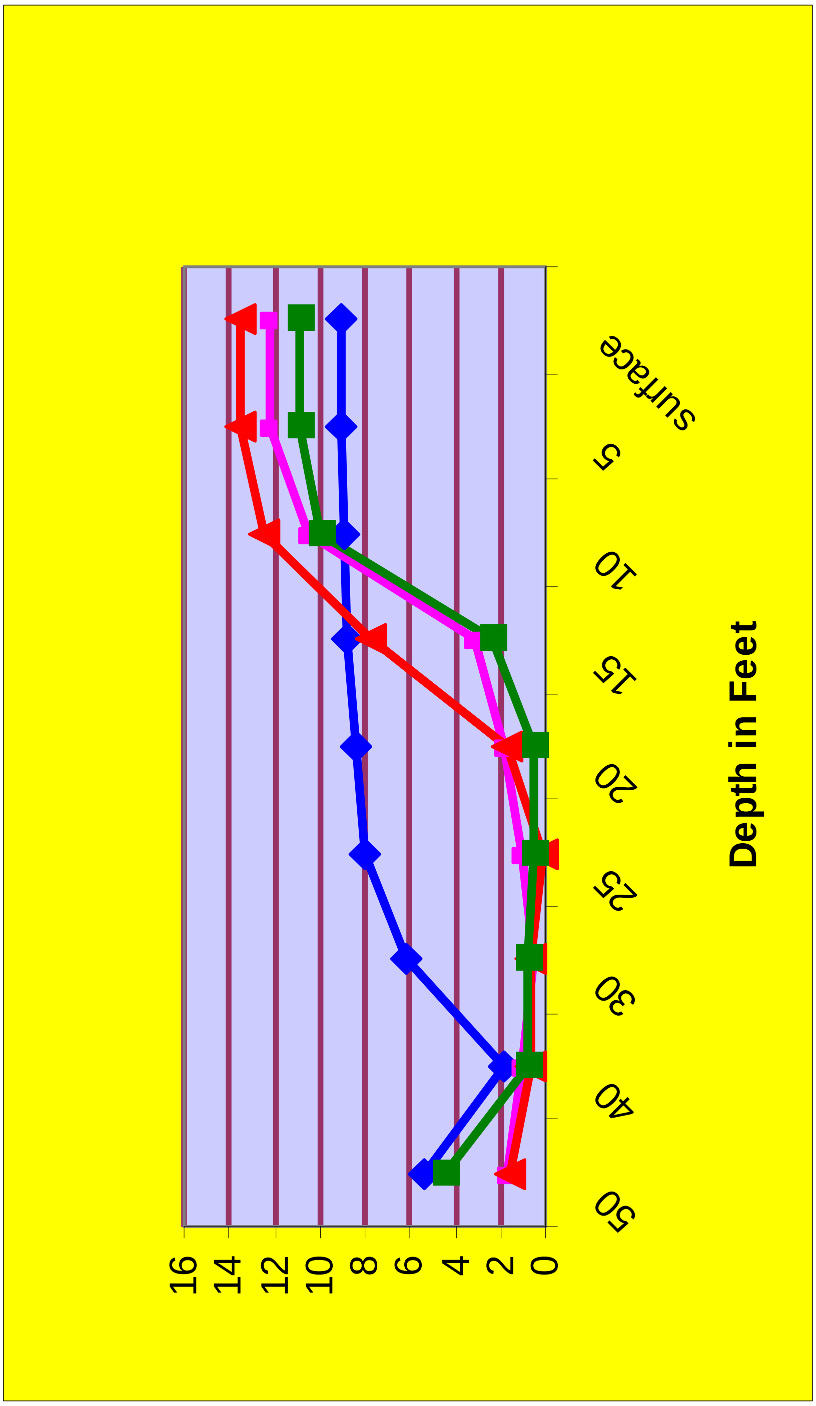


Figure 23a: Dissolved Oxygen Levels During 2004 Water Testing in milligrams/liter

Figure 23b: Dissolved Oxygen Levels During 2005 Water Testing in milligrams/liter

2/05

4/05

6/05

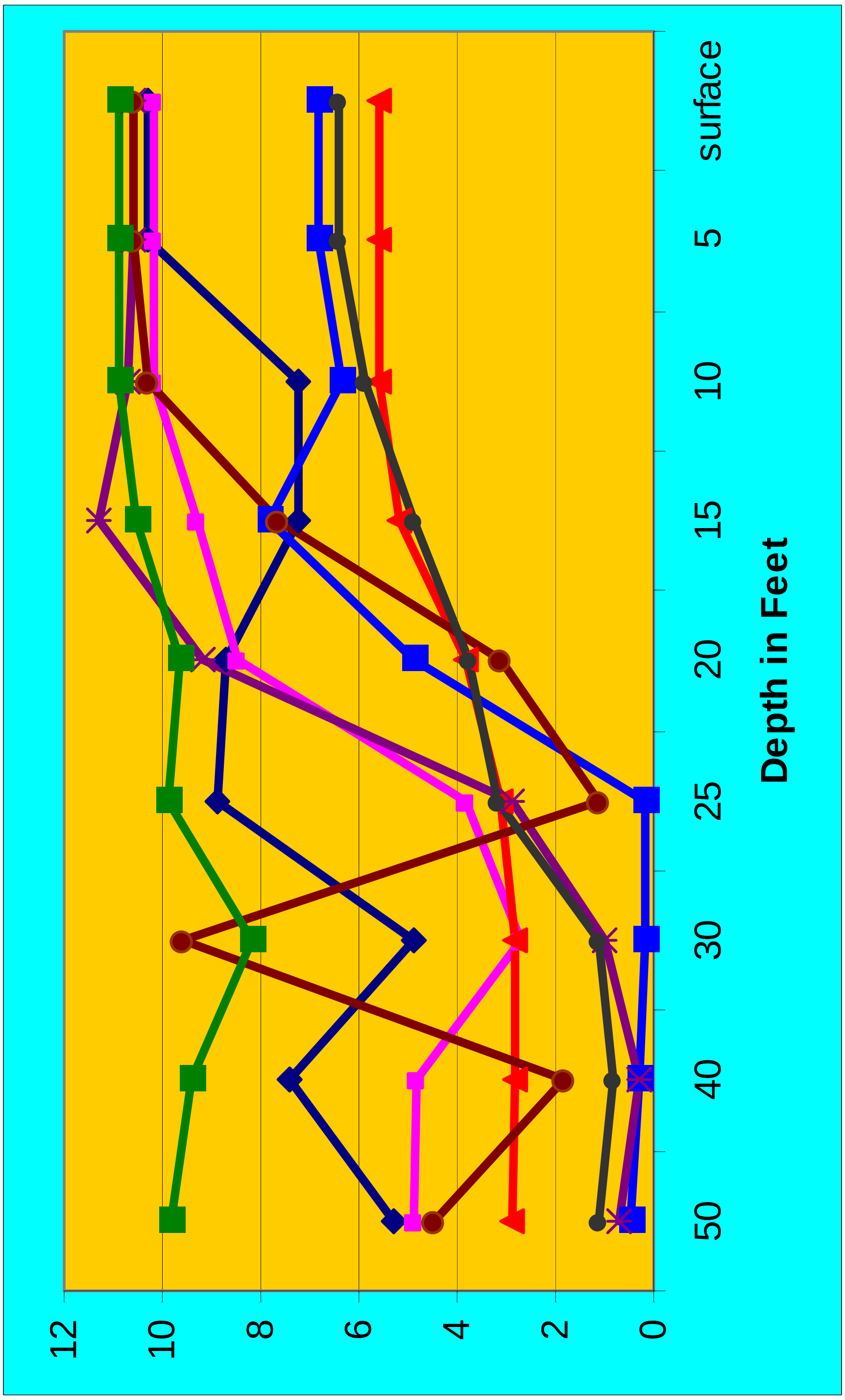
7/05

8/05

9/05

9/05

11/05



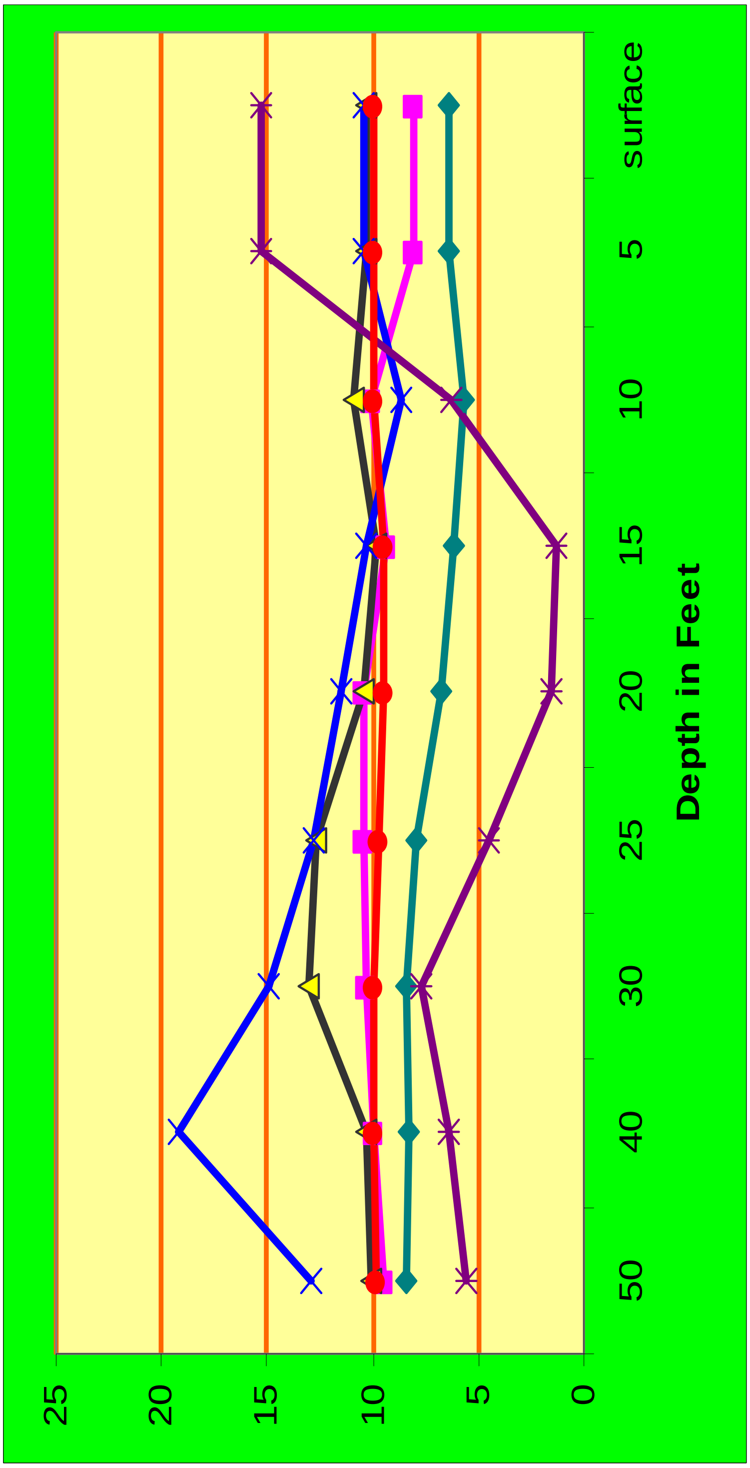


Figure23c: Dissolved Oxygen Levels During 2006 Water Testing in milligrams/liter

4/06

6/06

7/06

8/06

9/06

9/06

By autumn, when the surface waters have cooled and water density throughout the water column is the same, the water column mixes vertically, a process known as “fall turnover.”

Human activity can aggravate the development of low oxygen (hypoxic) or no oxygen (anoxic) in the bottom waters. For example, the addition of phosphorus usually leads to an increase in the growth of algae and aquatic plants—both of which consume oxygen during their photosynthesis. It has also been hypothesized that hypoxia or anoxia can be affected by climate changes, such as a longer and/or warmer summer, low lake levels, and changes in water temperature due to cover (i.e., shore vegetation) being removed.

The development of hypoxia or anoxia can have negative effects. The first effect usually noticed by human is fish kills. Fish kills result when fish species that need cold oxygen-rich water to survive can’t find it in the lake anymore or when some of their invertebrate food (such as mayfly nymphs) is gone due to low oxygen levels. Another noticeable effect can be an increase in the frequency and distribution of algal blooms. In some instances, anoxia can lead to blooms of toxic algae and the production of water-borne toxins that can harm humans and wildlife. Anoxia sometimes also leads to increased phosphorus cycling, undesirable water taste or odor levels, and interference with recreational uses such as swimming, boating and fishing.

As noted above, summer hypoxia or anoxia can result in phosphorus being released into the upper water column and being available for algal blooms and increased aquatic plant growth. The results from 2004 through 2006 (the only years for which data is available) don’t show that summer hypoxia/anoxia in the lower depths is always a problem in Crooked Lake, but it did show up in two of the three years.

The data from 2004-2006 (see Figures 22a, b, c) shows there is potential for phosphorus loading from the lower depths (hypolimnion) during the summer months in Crooked Lake if the hypoxia/anoxia continues. Dissolved oxygen needs to be monitored during the late summer months in the lower depths on Crooked Lake to determine whether hypoxia/anoxia is a frequently-occurring condition that may need to be addressed by management practices.

Water Hardness, Alkalinity and pH

Testing done by Adams County LWCD on Crooked Lake included annual testing for water alkalinity and water hardness. Hardness and alkalinity levels in a lake are affected by the soil minerals, bedrock type in the watershed, and frequency of contact between lake water & these materials.

Level of Hardness	Mg/l CaCO3
SOFT	0-60
MODERATELY HARD	61-120
HARD	121-180
VERY HARD	>180

Figure 24: Levels of Hardness in Mg/l of Calcium Carbonate

One method of evaluating hardness is to test the water for the amount of calcium carbonate ($CaCO_3$) it contains. The surface water of all of the public access lakes in Adams County is moderately hard to very hard. In 2005 and 2006, random samples were also taken of wells around Crooked Lake to measure the hardness of the water coming into the lake through groundwater. Hardness in the groundwater ranged from 172 (hard) to 288 (very hard). The hardness in both surface and groundwater is likely due to the underlying bedrock in Adams County, which is mostly sandstone with pockets of dolomite and shale.

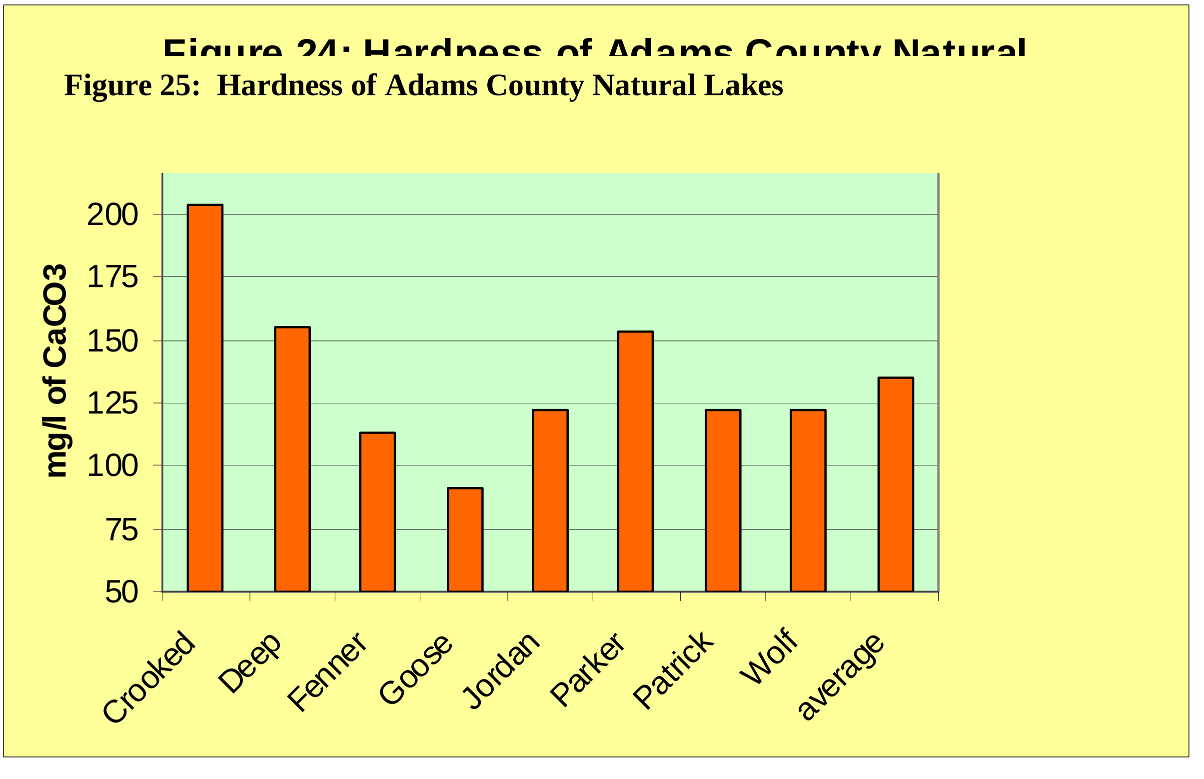


Figure 25: Hardness of Adams County Natural Lakes

As the graph (Figure 25) shows, Crooked Lake surface water testing results showed "hard" water" (over 200 mg/l of CaCO3), which is a higher hardness than the average for Adams County's natural lakes (135 mg/l of Calcium Carbonate). Hard water lakes tend to produce more fish and aquatic plants than soft water lakes because they are often located in watersheds with soils that load phosphorus into the lake water.

However, hard water lakes also often have marl sediments that precipitate the phosphorus out, serving to help balance the phosphorus loaded from the watershed. Hardness levels over 180 mg/l can cause marl to start precipitating out of the water or sediment, thus releasing phosphorus for aquatic plant and algae use. Since Crooked Lake's hardness less is above that number, the marl sediments in the lake may release phosphorus into in the water column.

Alkalinity is important in a lake to buffer the effects of acidification from the atmosphere. "Acid rain" has long been a problem with lakes that had low alkalinity level and high potential sources of acid deposition.

Acid Rain Sensitivity	ueq/l CaCO3
High	0-39
Moderate	49-199
Low	200-499
Not Sensitive	>500

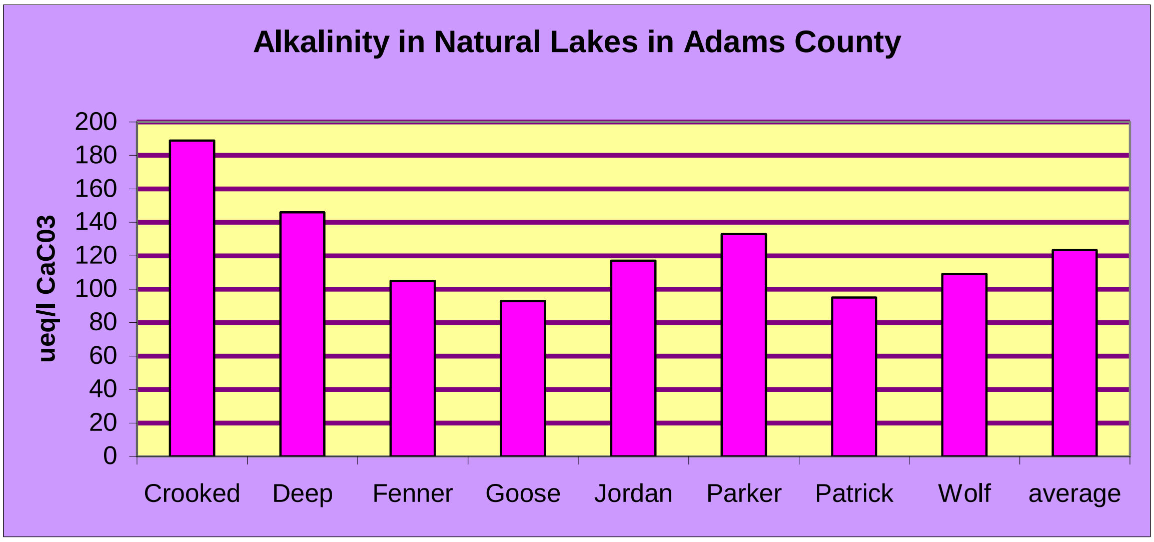
Figure 26: Acid Rain Sensitivity

Well water testing results ranged from 140 ueq/l to 228 ueq/l in alkalinity, about the same as the surface water results. Crooked Lake's potential sensitivity to acid rain is low to moderate, but luckily for Adams County, the acid deposition rate is very low, probably due to the little industrialization in the county.

Alkalinity also affects the pH level of lake water. The acidity level of a lake's water regulates the solubility of many minerals. A pH level of 7 is neutral. The pH level in Wisconsin lakes ranges from 4.5 in acid bog lakes to 8.4 in hard water, marl lakes.

Some of the minerals that become available under low pH, especially the metals aluminum, zinc and mercury, can inhibit fish reproduction and/or survival. Even what seems like a small variance in pH can have large effects because the pH scale is set up so that every 1.0 unit change increases acidity tenfold, i.e., water with a pH of 7 is 10 times more acid than water with pH of 8. Mercury and aluminum are not only toxic to many kinds of wildlife; they can also be toxic to humans, especially those that eat tainted fish.

Figure 27: Alkalinity in Natural Lakes in Adams County



The testing occurring from 2004-2006 also included regular monitoring of the pH at several depths in Crooked Lake. As is common in the lakes in Adams County, Crooked Lake has pH levels starting at just under neutral (6.33) at 50' depth and increasing in alkalinity as the depth gets less, until the surface water pH averages 7.36. A lake's pH level is important for the release of potentially harmful substances and also affects plant growth, fish reproduction and survival. Most plants grow best at pH levels between 5.5 and 8.

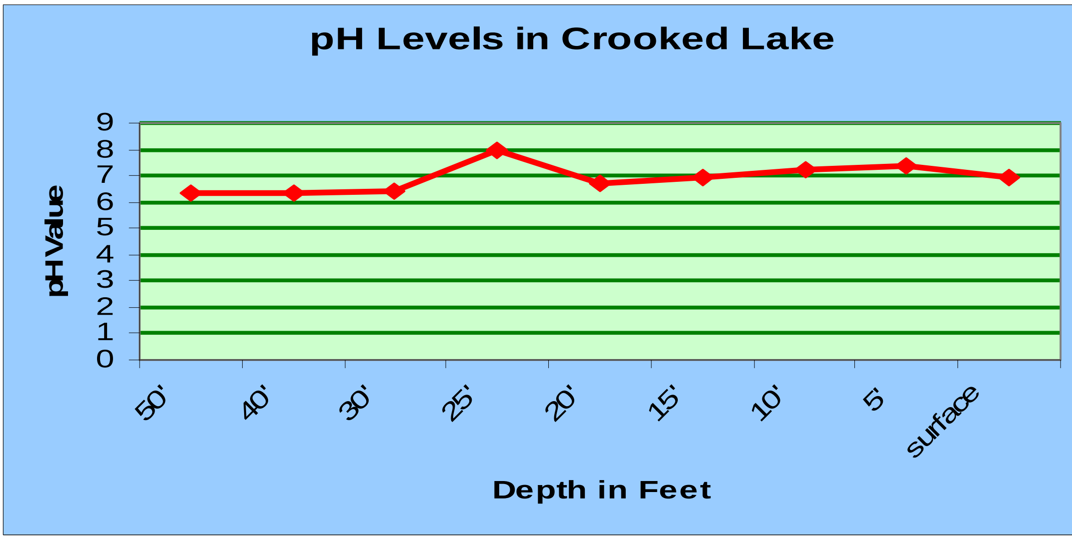


Figure 28: pH Average levels in Crooked Lake

More importantly for many lakes, fish reproduction and survival are very sensitive to pH levels. The chart below indicates the effect of pH levels under 6.5 on fish (Figure 28):

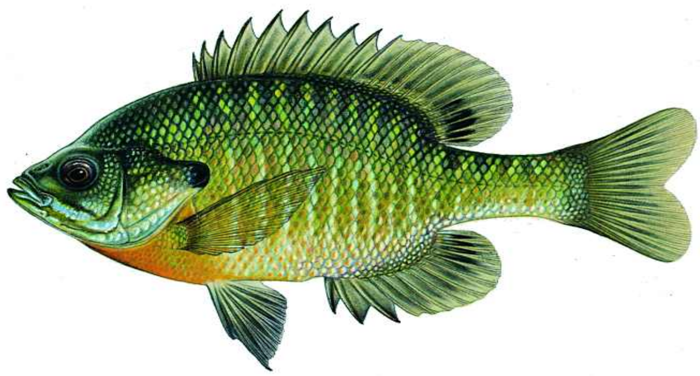
Figure 29: Effects of pH Levels on Fish

Water pH	Effects
6.5	walleye spawning inhibited
5.8	lake trout spawning inhibited
5.5	smallmouth bass disappear
5.2	walleye & lake trout disappear
5	spawning inhibited in most fish
4.7	Northern pike, sucker, bullhead, pumpkinseed, sunfish & rock bass disappear
4.5	perch spawning inhibited
3.5	perch disappear
3	toxic to all fish

Although pH levels at the 30'-50' depths in Crooked Lake sometimes fall below the pH level that inhibits walleye reproduction, spawning tends to occur in shallower waters where Crooked Lake has a good pH level for fish reproduction and survival.

A lake with a neutral or slightly alkaline pH like Crooked Lake is a good lake for fish and plant survival. Natural rainfall in Wisconsin averages a pH of 5.6. This means that if the rain falls on a lake without sufficient alkalinity to buffer that acid water coming in by rainfall, the lake's fish cannot reproduce. That is not a problem at Crooked Lake.

Figure 30: Common Fish in Crooked Lake: Bluegill



Other Water Quality Testing Results

CALCIUM and MAGNESIUM: Calcium is required by all higher plants and some microscopic lifeforms. Magnesium is needed by chlorophyllic plants and by algae, fungi and bacteria. Both calcium and magnesium are important contributors to the hardness of a lake's waters. Magnesium elevated about 125 mg/l may have a laxative effect on some humans. Otherwise, no health hazards to humans and wildlife are known from these elements. The average Calcium level in Crooked Lake's water during the testing period was 39.5 mg/l. The average Magnesium level was 21.53 mg/l. Both of these are low-level readings.

CHLORIDE: Chloride does not affect plant and algae growth and is not known to be harmful to humans. It isn't common in most Wisconsin soils and rocks, so is usually found only in very low levels in Wisconsin lakes. However, the presence of a significant amount of chloride over a period of time indicates there may be negative human impacts on the water quality present from septic system failure, the presence of fertilizer and/or waste, deposition of road-salt, and other nutrients. An increased chloride level is thus a possible indication that too many nutrients are entering the lake. The chloride levels found in Crooked Lake during the testing period averaged 8.38, over the natural level of 3 mg/l of chloride in this area of Wisconsin. These levels should be further examined to determine what contributing factors are causing the increased chloride level.

NITROGEN: Nitrogen is necessary for plant and algae growth. A lake receives nitrogen in various forms, including nitrate, nitrite, organic, and ammonium. In Wisconsin, the amount of nitrogen in a lake's water often corresponds to the local land use. Although some nitrogen will enter a lake through rainfall from the atmosphere, that coming from land use tends to be in higher concentrations in larger amounts, coming from fertilizers, animal and human wastes, decomposing organic matter, and surface runoff. For example, the growth level of the exotic aquatic plant, Eurasian Watermilfoil (*Myriophyllum spicatum*) has been correlated with fertilization of lake sediment by nitrogen-rich spring runoff.

Nitrogen levels can affect other aspects of water quality. The sum of water testing results for nitrate, nitrite and ammonium levels of over .3 mg/l in the spring can be used to project the likelihood of an algal bloom in the summer (assuming sufficient phosphorus is also present). Crooked Lake combination nitrogen levels from 2004 to 2006 did rise to .35 mg/l, just above the .3 mg/l predictive level for algal blooms.

SODIUM AND POTASSIUM: These elements occur naturally only in low levels in Wisconsin waters and soils. Their presence may indicate human-caused pollution. Sodium is found with chloride in many road salts and fertilizers and is also found in human and animal waste. Potassium is found in many fertilizers and also found in animal waste. Increasing levels or one or both of these elements can indicate possible contamination from damaging pollutants. High levels of sodium have also been found to influence the development of a large population of cyanobacteria, some of which can be toxic to animals and humans. Both sodium and potassium levels in Crooked Lake are low: the average sodium level was 1.94 mg/l; the average potassium reading was .7 mg/l.

SULFATE: In low-oxygen waters (hypoxic), sulfate can combine with hydrogen and becomes the gas hydrogen sulfate, which smells like rotten eggs and is toxic to most aquatic organisms. Sulfate levels can also affect the metal ions in the lake, especially iron and mercury, by binding them up, thus removing them from the water column. To prevent the formation of hydrogen sulfate, sulfate levels of 10 mg/l are best. A health advisory kicks in at 30 mg/l. Crooked Lake sulfate levels averaged 8 mg/l during the testing period, far below either level.

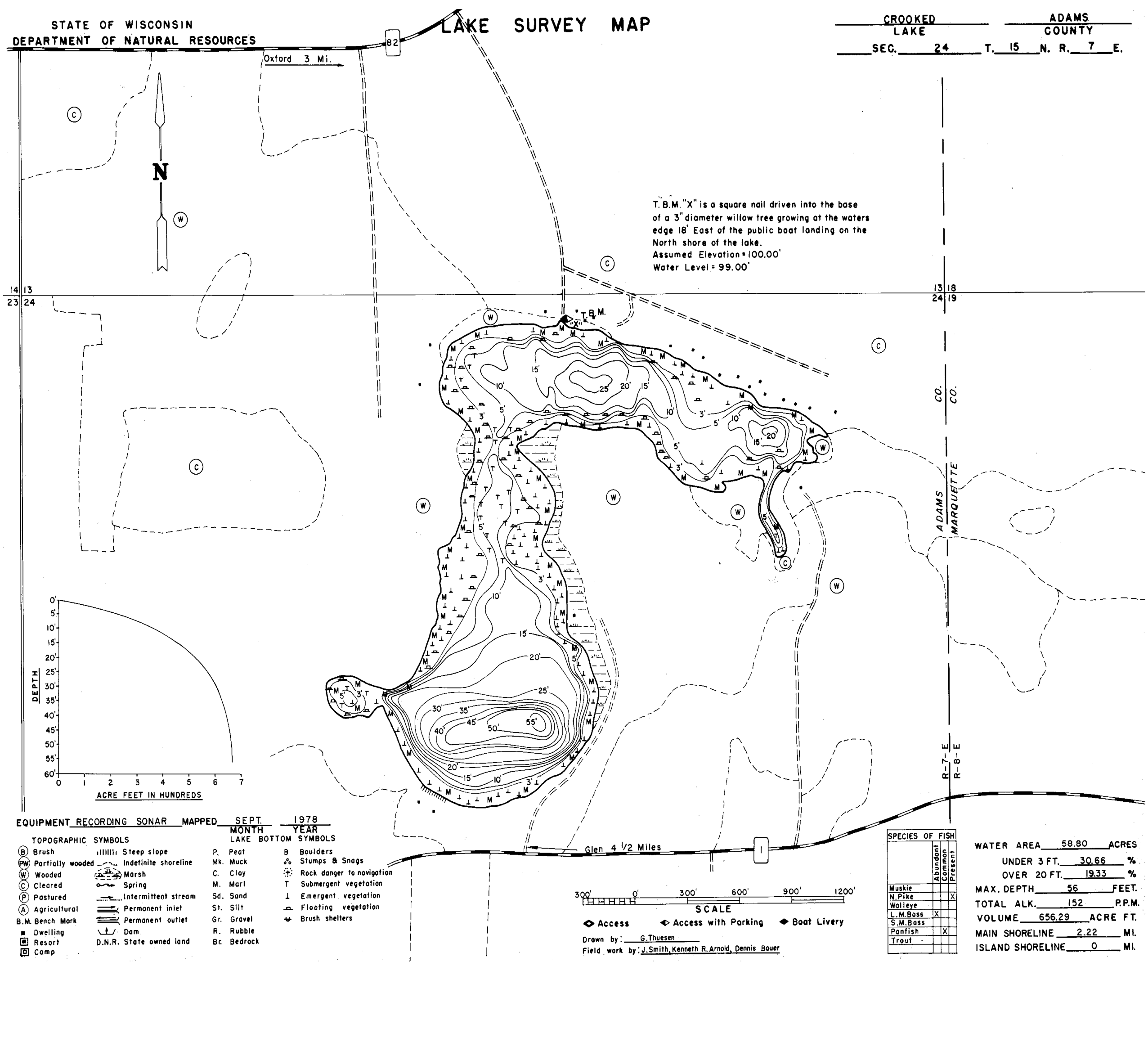
TURBIDITY: Turbidity reflects water clarity. The term refers to suspended solids in the water column—solids that may include clay, silt, sand, plankton, waste, sewage and other pollutants. Turbid water may mask the presence of bacteria or other pollutants because the water looks murky or muddy. In general, turbidity readings of less than 5 NTU are best. Very turbid waters may not only smell, but also tend to be aesthetically displeasing, thus curtailing recreational uses of the water. Turbidity levels for Crooked Lake's waters were 1.35 NTU in 2004, 1.8 NTU in 2005, and 1.8 NTU in 2006—all very low levels.

Figure 31: Examples of Very Turbid Water

HYDROLOGIC BUDGET

Crooked Lake has a surface area of **58.8 acres.** According to the 1941 bathymetric (depth) map (the most recent one available), the volume of the lake is **649.3 acre-feet**, and the mean depth is **11.2 feet**. The maximum depth is 58 feet.

Figure 32: Crooked Lake Bathymetric Map

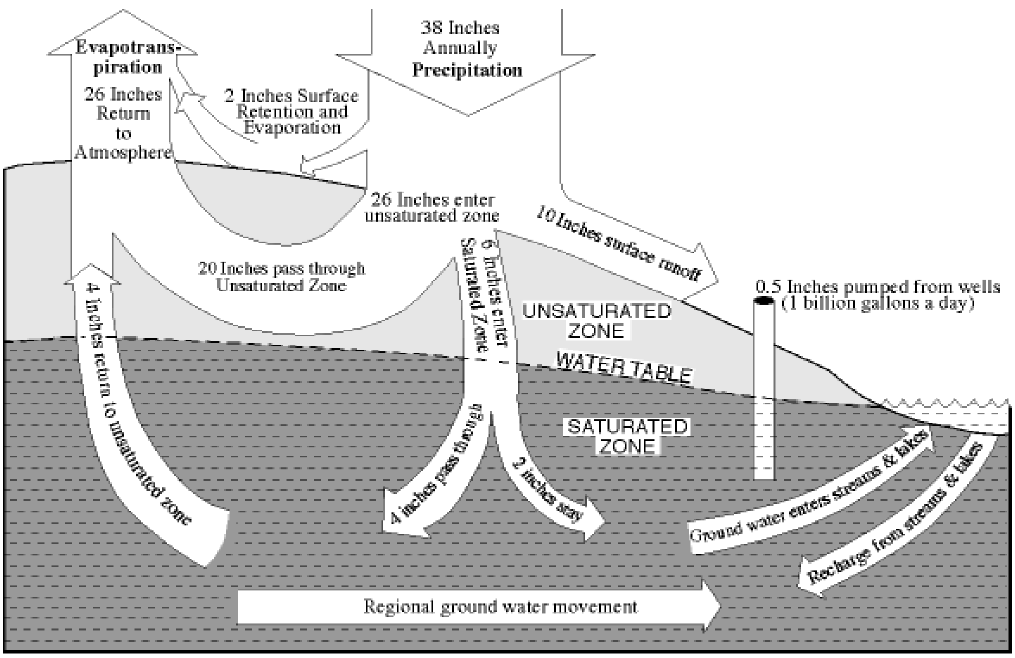


A “hydrologic budget” is an accounting of the inflow to, outflow from and storage in a hydrological unit (such as a lake). “Residence time” is the average length of time particular water stays within a lake before leaving it. This can range from several days to years, depending on the type of lake, amount of rainfall, and other factors. The “drainage area” is the amount of area (in acres) contributing surface water runoff and nutrients to the lake. The “areal water load” is the total annual flow volume reaching the lake divided by the surface area of the lake. “Hydraulic loading” is the total annual volume of all water sources (including precipitation, non-point sources & point sources) loading into the lake.

Using the data gathered from historical testing and that done by the Adams County LWCD from 2004-2006, the WiLMS model calculated the tributary drainage area for Crooked Lake as 2129.7 acres. The average unit runoff for Adams County in the Crooked Lake area is 9.4 inches. WiLMS determined the expected annual runoff volume as 1668.3 acre-feet/year. Anticipated annual hydraulic loading is 1681 acre-feet/year. Areal water load is 28.6 feet/year.

In a seepage lake like Crooked Lake, water and its nutrient load tend to stay longer within the lake before leaving it than in a lake with an inlet and/or outlet—in Crooked Lake’s case, modeling estimates a water residence of .39 years.

Figure 33: Example of Hydrologic Budget



TROPHIC STATE

The trophic state of a lake is one measure of water quality, basically defining the lake's biological production status (See Figure 34). **Eutrophic lakes** are very productive, with high nutrient levels, frequent algal blooms and/or abundant aquatic plant growth. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small populations of fish. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; often with a more varied fishery than either the eutrophic or oligotrophic lakes. In comparing water quality testing results with the prediction from the computer modeling of this modeling with the actual figures outlined above, the actual Trophic State of Crooked Lake is what was predicted from the modeling. Modeling results predicted that the overall TSI for Crooked Lake would be **42**. This score places Crooked Lake's overall TSI at about average for natural lakes in Adams County.

Figure 34: Trophic Status Table

Crooked Lake = 42 →

Score	TSI Level Description
30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth and occasional algal blooms; may have low oxygen levels near bottom in summer
50-60	**Mildly Eutrophic:** decreased water clarity; anoxic near bottom; may have heavy algal bloom and plant growth; high in nutrients; shallow eutrophic lakes may have winterkill of fish; rough fish common
60-70	**Eutrophic:** dominated by blue-green algae; algae scums common; prolific aquatic plant growth; high nutrient levels; rough fish common; susceptible to oxygen depletion and winter fishkill
70-80	**Hypereutrophic:** heavy algal blooms through most of summer; dense aquatic plant growth; poor water clarity; high nutrient levels

Phosphorus concentration, chlorophyll-a concentration and water clarity data are collected and combined to determine a trophic state. As discussed earlier, the average summer epilimnetic total phosphorus for Crooked Lake was 18.8 micrograms/liter. The average summer chlorophyll-a concentration was 4.4 micrograms/liter. Growing season water clarity averaged a depth of 10.6 feet. Figure 35 shows where each of these measurements from Crooked Lake fall in trophic level.

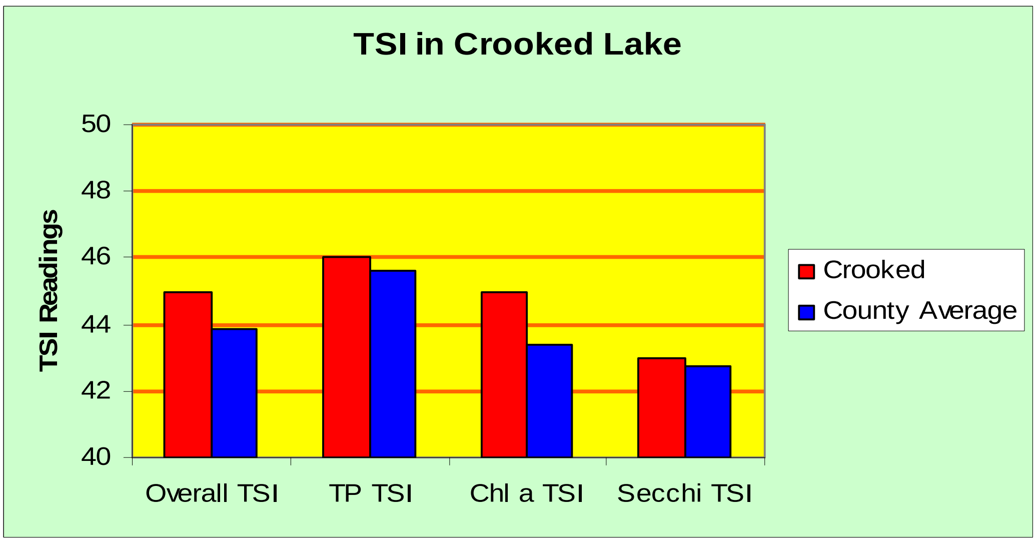
Figure 35: Crooked Lake Trophic Status Overview

Trophic State	Quality Index	Phosphorus (ug/l)	Chlorophyll a (ug/l)	Sechhi Disk (ft)
Oligotrophic	Excellent	<1	<1	>19
	Very Good	1 to 10	**1 to 5**	**8 to 19**
Mesotrophic	Good	**10 to 30**	5 to 10	6 to 8
	Fair	30 to 50	10 to 15	5 to 6
Eutrophic	Poor	50 to 150	15 to 30	3 to 4
Crooked Lake		**18.8**	**4.4**	**10.6**

These figures show that Crooked Lake has low levels overall for the three parameters often used to describe water quality: Secchi disk depths; average TP for the growing season; and chlorophyll a levels. It is normal for all of these values to fluctuate during a growing season. However, they can be affected by human use of the lake, by summer temperature variations, by algae growth & turbidity, and by rain or wind events. According to these results, Crooked Lake scores as **"**mesotrophic**"** in its phosphorus level, and "oligotrophic" in chlorophyll-a readings and Secchi disk readings. With such phosphorus readings and chlorophyll a readings, dense plant growth and frequent algal blooms would not be expected.

Crooked Lake ranks slightly higher in all parameters than the average natural lake in Adams County, as shown in Figure 36. In the TSI index, this is not a positive factor.

Figure 36: TSI for Crooked Lake & County Average



IN-LAKE HABITAT

Aquatic Plants

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in improving water quality, providing valuable habitat resources for fish and wildlife, resisting invasions of non-native species and checking excessive growth of the most tolerant species.

An aquatic plant survey was done on Crooked Lake in the summer of 2005 by staff from the WDNR and the Adams County LWCD. The results verified that Crooked Lake is a borderline mesotrophic/oligotrophic lake with very good water quality and excellent water clarity, although nutrient level and algae frequency have increased since 1997. Filamentous algae are present in Crooked Lake, with the lowest presence found in the 0-1.5' depth zone.

The aquatic plant community colonized approximately half of Crooked Lake, with 100% of the littoral zone covered to a maximum rooting depth of 12.5 feet. The 0 to 1.5 foot depth zone supported the most abundant aquatic plant growth. Species richness was 4.6 in the lake. The Crooked Lake aquatic plant community is characterized by above average quality and very good species diversity. The plant community is closer to an undisturbed condition than the average lake in the state.

Chara spp.(muskgrass) was the dominant species. *Nymphaea odorata* (white water-lily) was sub-dominant. The most common species were found distributed throughout the lake. Several species showed more than average density of growth where present.

Figure 37: *Eleocharis quandrangulata* (square-stem spikerush)—an endangered species found at Crooked Lake

Figure 38: Crooked Lake Aquatic Plant Species 2005

Scientific Name	Common Name
Emergent Species	
1) *Carex* spp .	sedge
2) *Eleocharis quandrangulata* (Michx) Roem & Schult	creeping spikerush
3) *Eleocharis smaillii* Britt.	Creeping spikerush
4) *Sagittaria* spp*.*	arrrowhead
5) *Scirpus validus* Vahl.	softstem bulrush
6) *Sparganium eurycarpum* Engelm.	giant bur-reed
7) *Typha latifolia* L.	common cattail
Floating-leaf Species	
8) *Lemna minor* L.	small duckweed
9) *Nuphar variegta* Durand.	bull-head pond lily
10) *Nymphaea odorata* Aiton.	white water lily
11) *Spirodela polyrhiza* (L.) Schleiden.	great duckweed
Submergent Species	
12) *Ceratophyllum demersum* L.	coontail
13) *Chara* sp.	muskgrass
14) *Myriophyllum heterophyllum* Michx.	variable-leaf water-milfoil
15) *Myriophyllum sibiricum* Komarov.	common water milfoil
16) *Myriophyllum spicatum* L.	Eurasian water milfoil
17) *Najas flexilis* (Willd.) Rostkov & Schmidt	slender naaid
18) *Potamogeton gramineus* L.	variable-leaf pondweed
19) *Potamogeton natans* L.	floating-leaf pondweed
20) *Potamogeton pectinatus* L.	sago pondweed
21) *Potamogeton zosteriformis* Fern.	flatstem pondweed
22) *Utricularia gibba* L. .	small bladderwort
23) *Utricularia vulgaris* L.	great bladderwort

The study used the results of the 2005 field survey to evaluate Crooked Lake by using several standard community measurements. For example, the Simpson's Diversity Index was 0.90, indicating very good species diversity. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Crooked Lake is 53. This is above average for lakes in Wisconsin and average for the North Central Hardwoods Region of the state.

The Average Coefficient of Conservatism for Crooked Lake was 5.48, below average for Wisconsin lakes (6.0) and lakes in the North Central Hardwood (5.6) Region. This suggests that the aquatic plant community in Crooked Lake is less sensitive to disturbance than the average lake in the state or region. This is likely due to selection of species by past disturbance.

The Floristic Quality Index of the aquatic plant community in Crooked Lake was 25.10, in the upper quartile of Wisconsin lakes (average 22.2) and North Central Hardwood Region lakes (average 20.9). This indicates that the plant community in Crooked Lake is within the group of lakes in the state and region closest to an undisturbed condition.

Eurasian watermilfoil, a non-native, invasive plant species, is a critical threat to habitat and native plant species. It was found near the boat ramp in 2005. It was checked again in 2006 and 2007, revealing that it had spread further along the shore of the lake, but has not yet been found in waters over 5' deep. Disturbance, such as that where the boats come in & travel to other parts of the lake, creates an ideal condition for exotic species to colonize and spread.

Plant distribution, frequency and density varied considerably within Crooked Lake, depending on the plant types (see Figure 39).

Figure 39: Aquatic Plants in Crooked Lake 2005

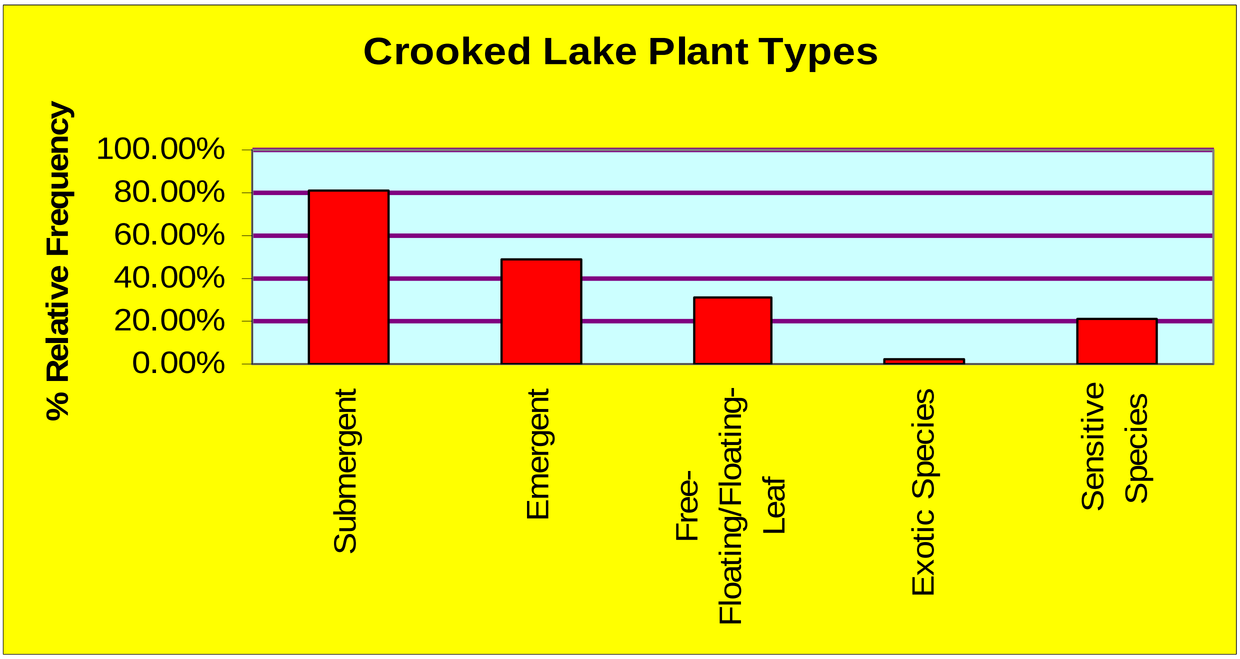
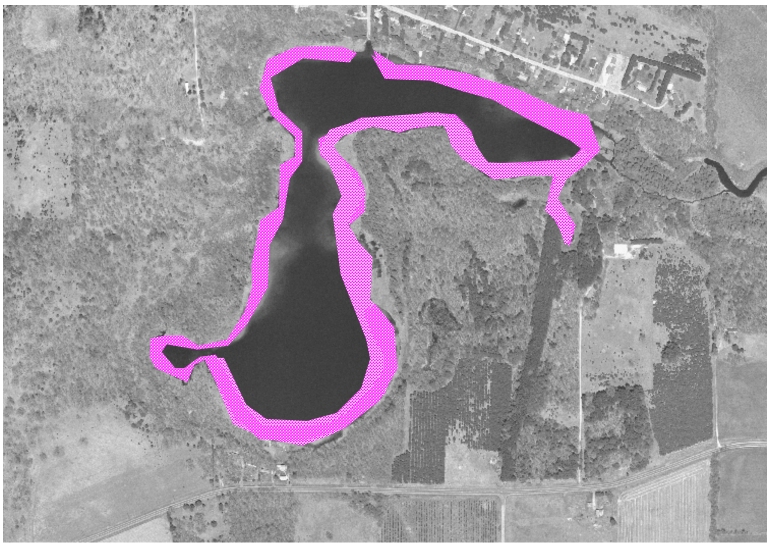


Figure 40a: Emergent Aquatic Plants in Crooked Lake (2005)

RE:2/07

Emergent Plants Found

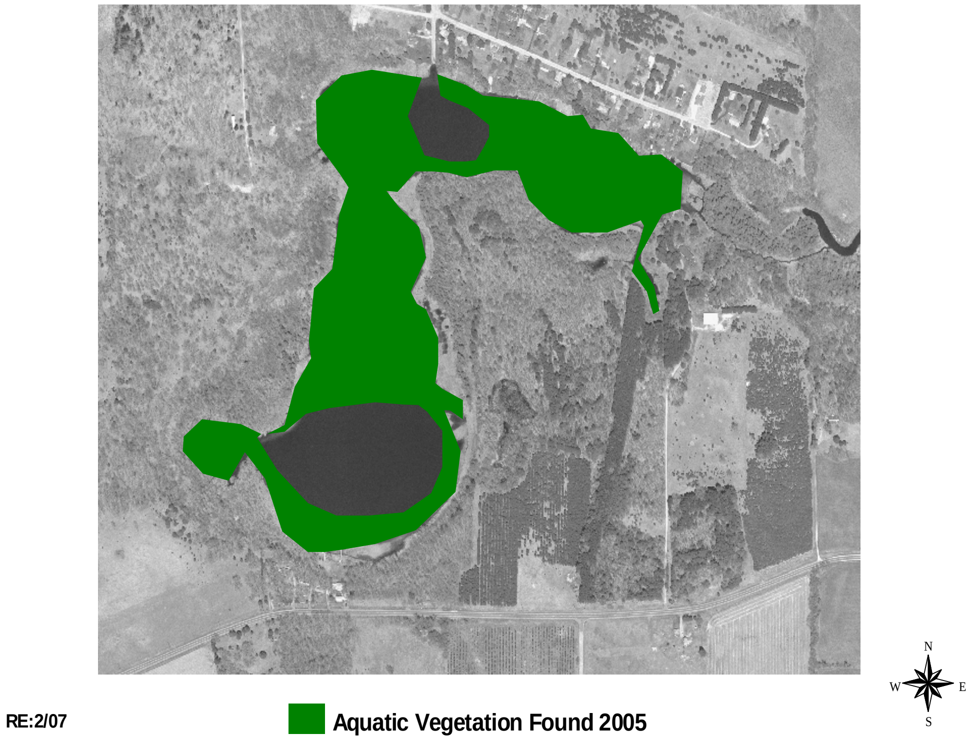
Figure 40b: Free-Floating & Floating Leaf Plants in Crooked Lake



RE:2/07

Floating Plants Found

Figure 40c: Submergent Aquatic Species in Crooked Lake (2005)



Chara spp (Muskgrass)

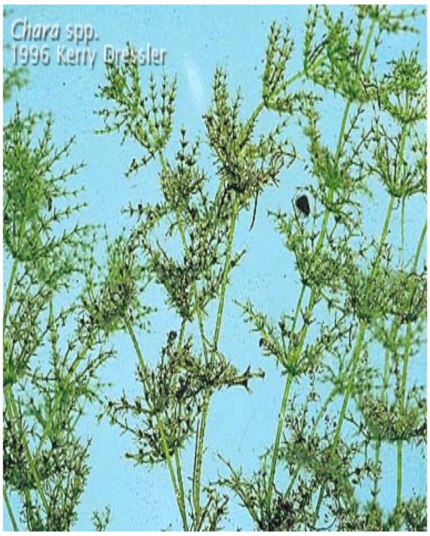
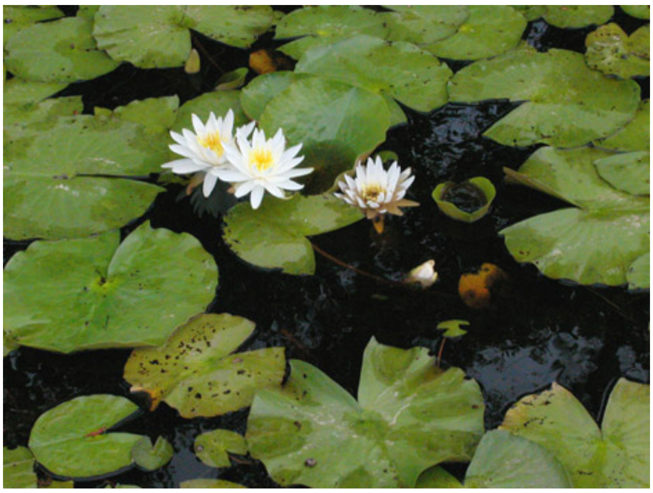


Figure 41: Most Common Native Aquatic Species in Crooked Lake

Nymphaea odorata **(White Water Lily)**



Aquatic Invasives

Eurasian Watermilfoil was introduced in Crooked Lake shortly before it was found in July 2005, when it was found directly to the left of the boat ramp and directly across from it. However, by summer 2007, it had moved along the lakeshore in both directions from the boat ramp. The Crooked Lake Association expects to continue monitoring the Eurasian Watermilfoil population and take necessary treatment steps to keep it managed. Figure 42 shows where the plant was originally found in 2005 (pink). Figure 43 indicates where it was found in 2007 (white), as well as the other spot in 2005 (yellow) which was free of EWM in 2007.

In addition, a survey in 2007 indicated that the native weevil, *Euhrychiopsis lecontei*, was present in parts of Crooked Lake. This weevil, if present in sufficient density, can weaken Eurasian milfoil plants to the point of death.

Figure 42: Distribution of Exotic Aquatic Plants in 2005

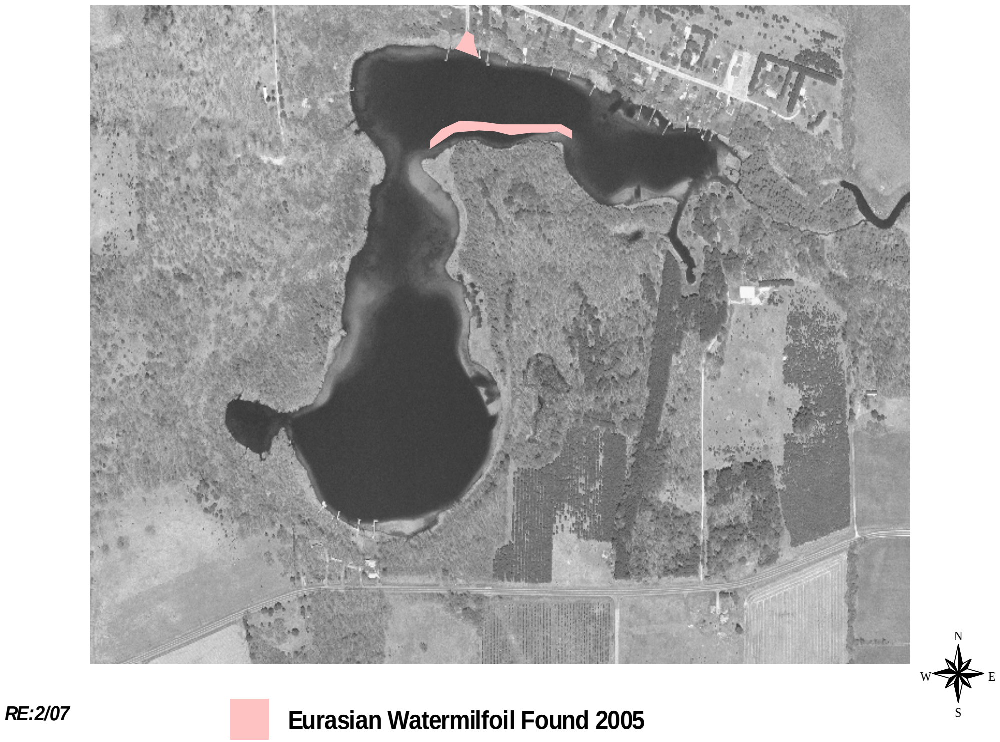


**Figure 43: Crooked Lake EWM Locations in 2005 & 2007
(2005 shown in yellow; 2007 shown in white)**

So far, other invasives have not been found at Crooked Lake. However, ongoing monitoring for invasives should occur, especially since the improvement of the boat ramp seems to have increased outside boat traffic to the lake.

Figure 44:
Myriophyllum spicatum
(Eurasian Watermilfoil)

Critical Habitat

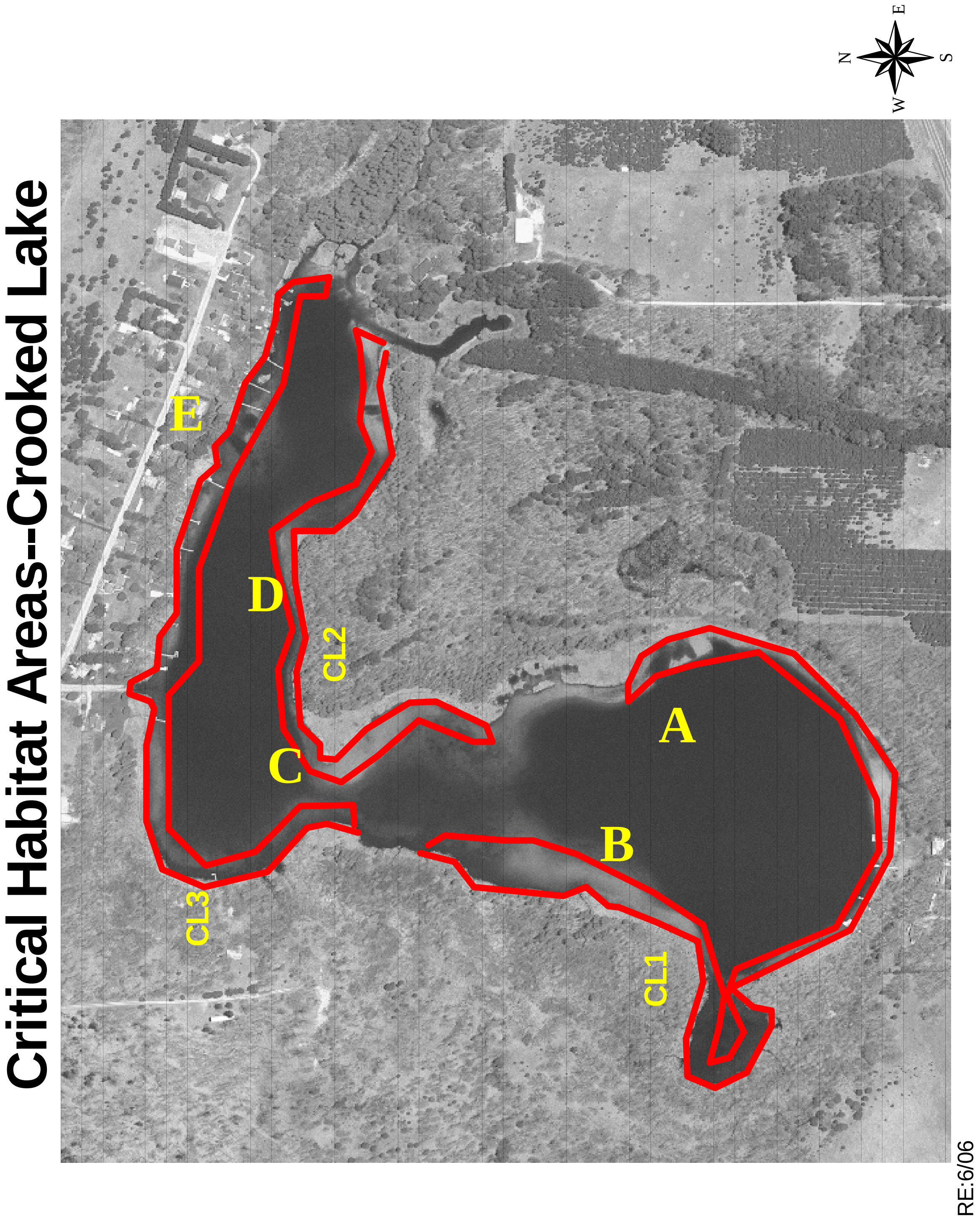
Designation of critical habitat areas within lakes provides a holistic approach for assessing the ecosystem and for protecting those areas in and near a lake that are important for preserving the qualities of the lake. Wisconsin Rule 107.05(3)(i)(I) defines a "critical habitat areas" as: "areas of aquatic vegetation identified by the department as offering critical or unique fish & wildlife habitat or offering water quality or erosion control benefits to the body of water. Thus, these sites are essential to support the wildlife and fish communities. They also provide mechanisms for protecting water quality within the lake, often containing high-quality plant beds. Finally, critical habitat areas often can provide the peace, serenity and beauty that draw many people to lakes.

Protection of critical habitat areas must include protecting the shore area plant community, often by buffers of native vegetation that absorb or filter nutrient & stormwater runoff, prevent shore erosion, maintain water temperature and provide important native habitat. Buffers can serve not only as habitats themselves, but may also provide corridors for species moving along the shore.

Besides protecting the landward shore areas, preserving the littoral (shallow) zone and its plant communities not only provides essential habitat for fish, wildlife, and the invertebrates that feed on them, but also provides further erosion protection and water quality protection.

Field work for a critical habitat area study was performed on June 6, 2006, on Crooked Lake, Adams County. The field study team included: Scot Ironside, DNR Fish Biologist; Deborah Konkel, DNR Aquatic Plant Specialist; and Reesa Evans, Adams County Land & Water Conservation Department. Input was also gained from Terry Kafka, DNR Water Regulation; Jim Keir, DNR Wildlife Biologist; and Buzz Sorge, DNR Lake Manager. Areas were identified visually, with GPS readings and digital photos providing additional information.

Figure 45: Critical Habitat on Crooked Lake



Sensitive Area CR1

This area extends along approximately 4200 feet of the shoreline. Sediment includes marl, muck, peat, sand, silt and mixtures thereof. 24% of the shore is wooded; 27% has shrubs; 49% is native herbaceous cover. Several types of wetlands are found along this shoreline: shallow marsh; deep marsh; sedge meadow; shrub-carr; and tamarack bog. Large woody cover is common for habitat. With virtually no human disturbance along this shoreline, the area has natural scenic beauty.

Figure 46: Sedge Meadow in CR1—Point A on map

A beaver lodge in the area suggested beaver use CR1. Muskrat and mink are also known to use this habitat for cover, reproduction and feeding. Seen during the field survey were various types of waterfowl, songbirds, and turkey. A sandhill crane nesting pair was also noted. Frogs and salamanders are known to use this area for shelter/cover, nesting and feeding. Turtles and snakes also use this area for cover or shelter in this area, as well as nested and fed in this area. Upland wildlife feed and nest here as well. Since human disturbance is especially light in CR1, it provides high-quality habitat for many types of wildlife.

Seventeen aquatic species were found in CR1, including three emergent aquatic plants, two floating-leaf rooted plants, two free-floating plants, and ten submergent plants. One threatened aquatic species, *Eleocharis quadrangulata*, was found along this sensitive area.

Figure 47: Tamarack Swamp at Crooked Lake—Point B on map

Sensitive Area CR2

This area extends along approximately 2900 feet of the shoreline. Sediment includes marl, peat, silt and mixtures thereof. 40% of the shore is wooded; 10% has shrubs; 50% is native herbaceous cover. Sedge meadow and tamarack bog wetlands are found along this shoreline. Large woody cover is abundant for habitat. With little human disturbance along this shoreline, the area is has natural scenic beauty.

This area of abundant large woody cover, emergent aquatic vegetation, submergent and floating vegetation provides spawning and nursery areas for many types of fish. . No exotic aquatic wildlife was noted in this area, i.e, no carp, smelt or rusty crayfish were seen. No shore development was present in CR2.

Figure 48: Sedge Meadow in CR2—See Point C on map

No threatened or endangered species were found in this area. One exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil), was found in this area. Of the eighteen aquatic plant species found here, three were emergent, two were floating-leaf rooted plants and thirteen were submergent.

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Figure 49: Tamarack Bog at Crooked Lake—See point D on map

SENSITIVE AREA CR3

This area extends along approximately 3300 feet of the shoreline. Sediment includes marl, muck, peat, sand, silt and mixtures thereof. 7% of the shore is wooded; 20% has shrubs; 57% is native herbaceous cover—the remaining 16% is cultivated lawn. This sensitive area includes the most developed area of Crooked Lake. However, there are areas of wetlands: shallow marsh; sedge meadow; conifer swamp. Large woody cover is present, but not as much as in the other two sensitive areas. Scenic beauty in part of the area is lessened due to the human development. Most development in this area has been carried out so as to preserve habitat and minimize negative human impact. Several spawning beds were observed in this area.

Figure 50: Some of CR3 Developed Areas—See Point E on map

One exotic invasive, *Myriophyllum spicatum* (Eurasian watermilfoil), was found in this area. 45% of the area has filamentous algae, especially near the shores. Of the seventeen aquatic plant species found here, four were emergent, one was free-floating, two were floating-leaf rooted plants and ten were submergent.

Recommendations for Critical Habitat Areas

(1) Maintain current habitat for fish and wildlife.
(2) Do not remove fallen trees along the shoreline.
(3) No alteration of littoral zone unless to improve spawning habitat.
(4) Seasonal protection of spawning habitat.
(5) Maintain snag/cavity trees for nesting.
(6) Leave nest boxes.
(7) Maintain or increase wildlife corridor.
(8) Maintain no-wake zone.
(9) Protect emergent vegetation, especially *Eleocharis quadrangulata.*
(10) Seasonal control of Eurasian Watermilfoil.
(11) Minimize aquatic plant and shore plant removal to maximum 30’ wide viewing/access corridor. Leave as much vegetation as possible to protect water quality and habitat.
(12) Use forestry best management practices.
(13) No use of lawn products.
(14) No bank grading or grading of adjacent land.
(15) No pier placement, boat landings, development or other shoreline disturbance in the shore area of the wetland corridor.
(16) No pier construction or other activity except by permit using a case-by-case evaluation.
(17) No installation of pea gravel or sand blankets.
(18) No bank restoration unless the erosion index scores moderate or high.
(19) If the erosion index does score moderate or high, bank restoration only using biologs or similar bioengineering, with no use of riprap or retaining walls.
(20) Placement of swimming rafts or other recreational floating devices only by permit.
(21) Maintain buffer of shoreline vegetation.
(22) Maintain aquatic vegetation buffer in undisturbed condition for wildlife habitat, fish use and water quality protection.

FISHERY/WILDLIFE/ENDANGERED RESOURCES

Stocking records for Crooked Lake go back to 1937, when northern pike and mixed panfish were stocked by the WDNR. Over the years since, the WDNR also stocked more mixed panfish, perch, largemouth bass, bullhead, northern pike, and both rainbow and brooked trout. Fish inventories from 1954 through 1985 found that largemouth bass, bullheads and panfish were common to abundant, while northern pike tended to be scarce. Trout apparently did not establish a breeding population, since an inventory three years after trout were last stocked found no trout present.

Muskrat and mink are also known to use Crooked Lake shores for cover, reproduction and feeding. A beaver lodge was noted during the critical habitat survey. Seen during the field survey were various types of waterfowl, songbirds, and turkey. Frogs and salamanders are known, using the lake shores for shelter/cover, nesting and feeding. Turtles and snakes also use this area for cover or shelter in this area, as well as nested and fed in this area. Sandhill cranes have also nested on Crooked Lake. Upland wildlife feed and nest here as well.

Crooked Lake Watershed shelters several natural communities designated by the WDNR as communities that are endangered: Calcareous fen; Emergent marsh; Northern sedge meadow; Oak barrens; Open bog; and Southern sedge meadow.

Figure 51: Common Fish in Crooked Lake—Largemouth Bass

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